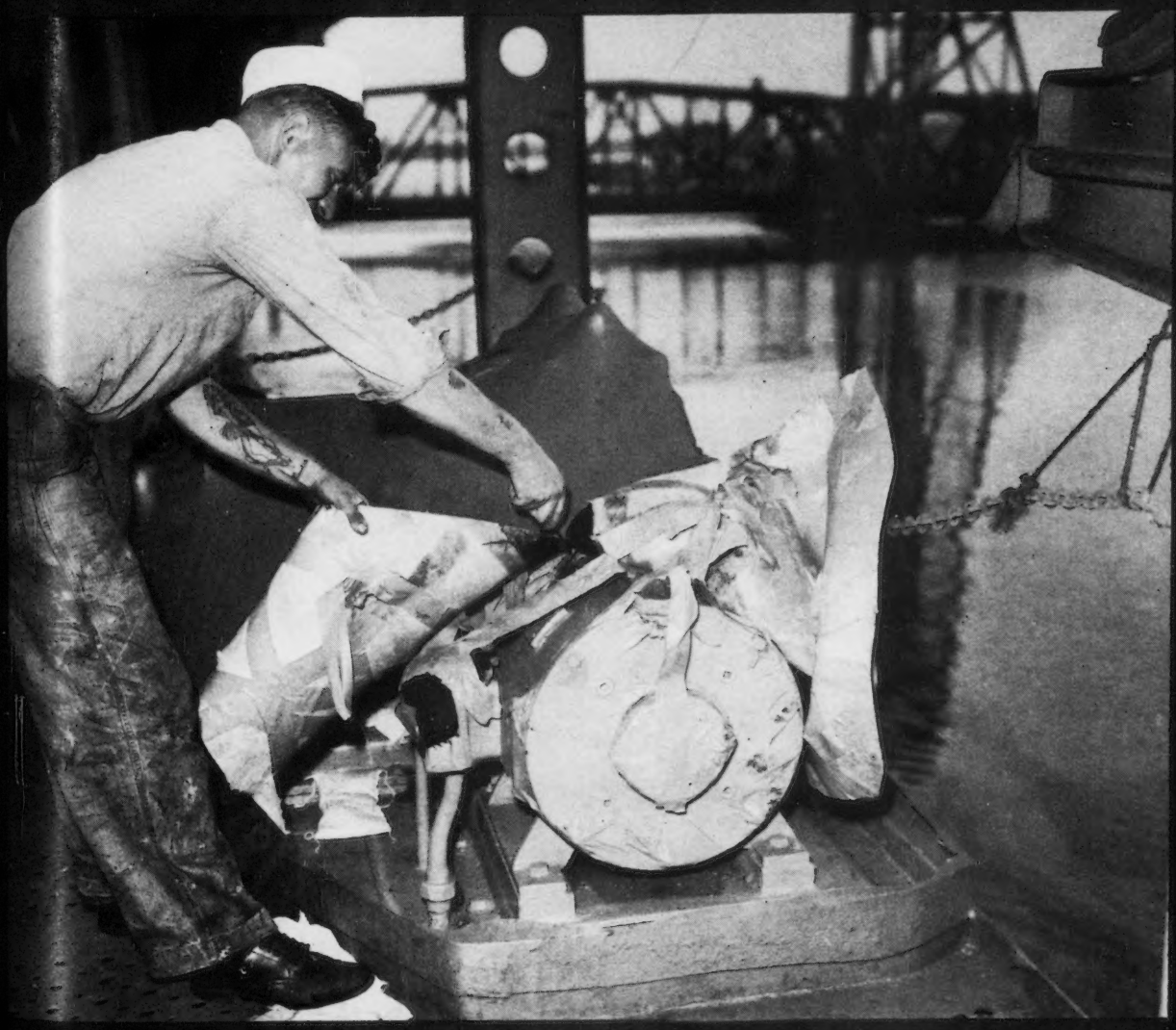
Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS



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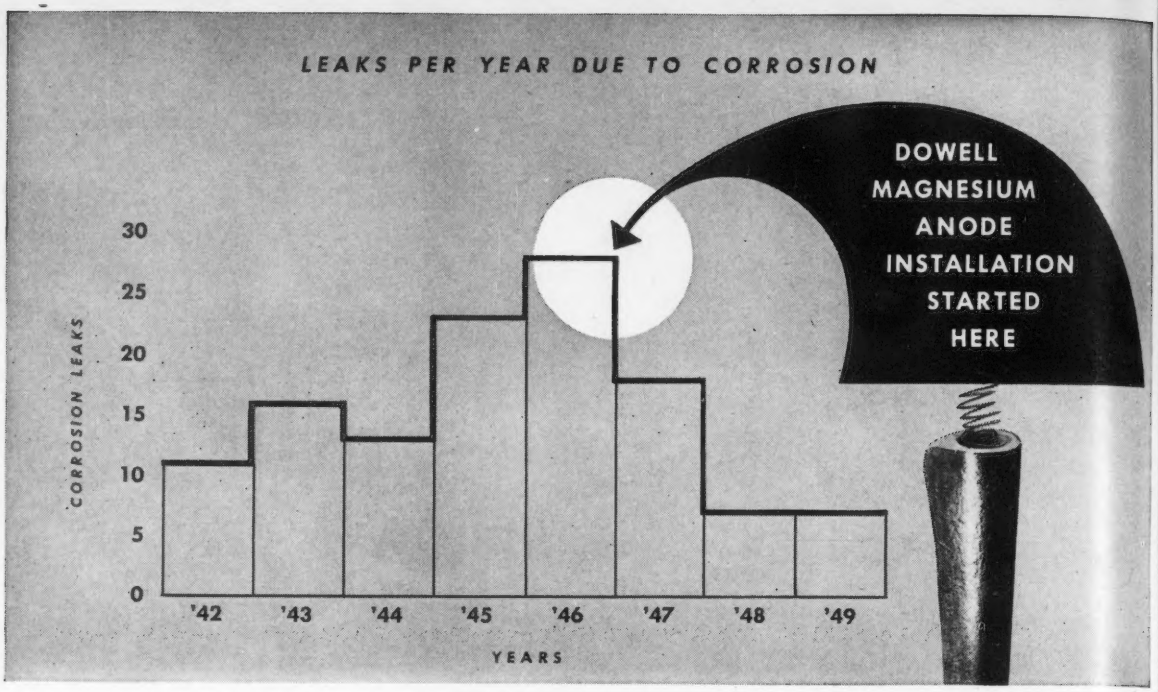

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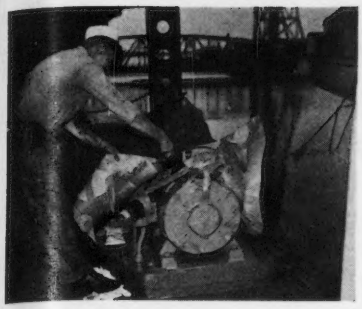

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Subscription: $7.50 per year to non-members; Member's dues $7.50, of which $3.00 are applied as subscription to CORROSION; Special rate, $3.50 per year for public libraries and libraries of educational institutions. Additional copies to members 50 cents, to non-members, 75 cents. Foreign remittances should be by international postal or express money order or bank draft negotiable in the U. S. for an equivalent amount in U. S. funds.

Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

Corrosion is Indexed Regularly by Engineering Index.

Corrosion devoted entirely to CORROSION Research and Control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., to provide a permanent record of progress in the control of corrosion as described in papers prepared for the Association and from other sources.

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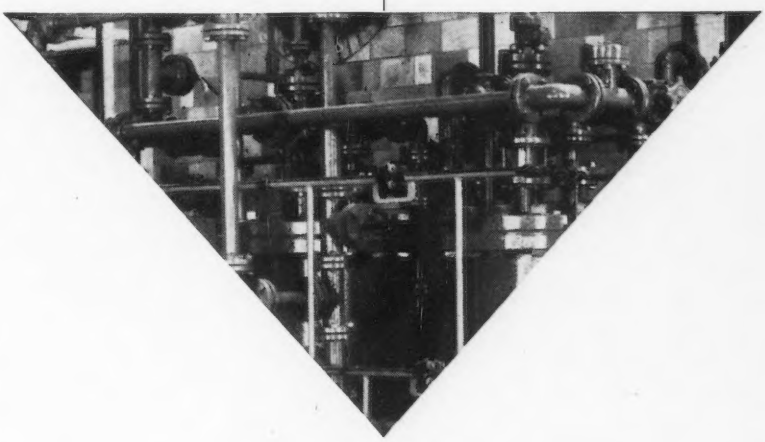

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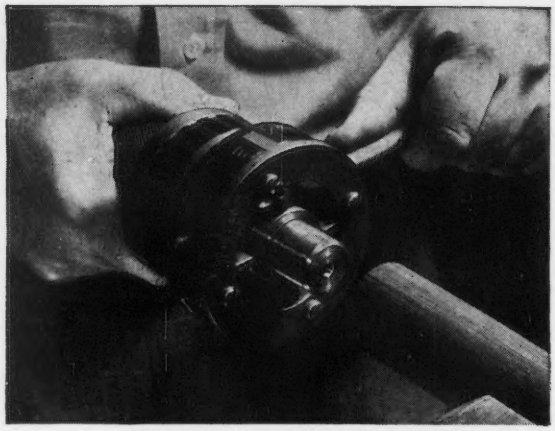

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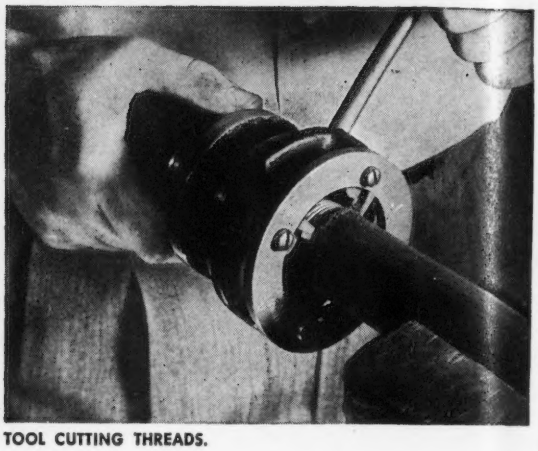

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TP-6H Glass Linings and Vitreous Enamel. G. H. McIntyre, Chairman. Ferro-Enamel Corp., Harvard & 56th St., Cleveland 5, Ohio.

TP-6I Metallic Coatings. (Chairman not appointed).

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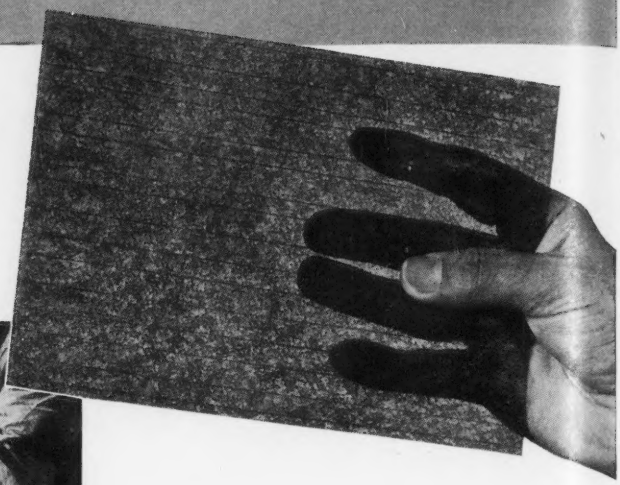

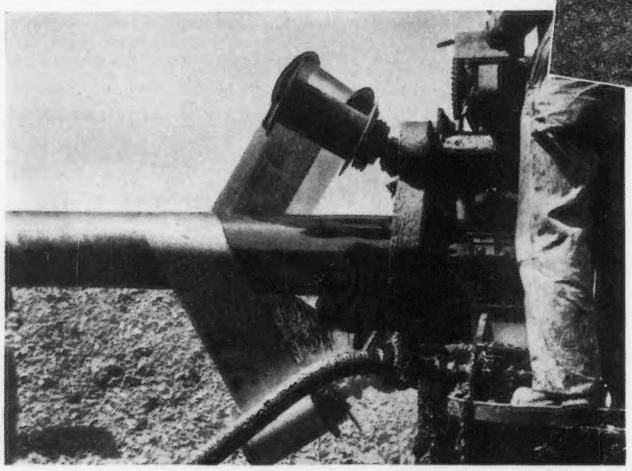

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Why wrap the hard way? Start now with the new Fiberglas Parallel Reinforced Coromat—the product of experience! Owens-Corning Fiberglas Corporation, Dept. 53-L, Toledo 1, Ohio.

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FIBERGLAS IS ~~IN YOUR LIFE~~...FOR GOOD!

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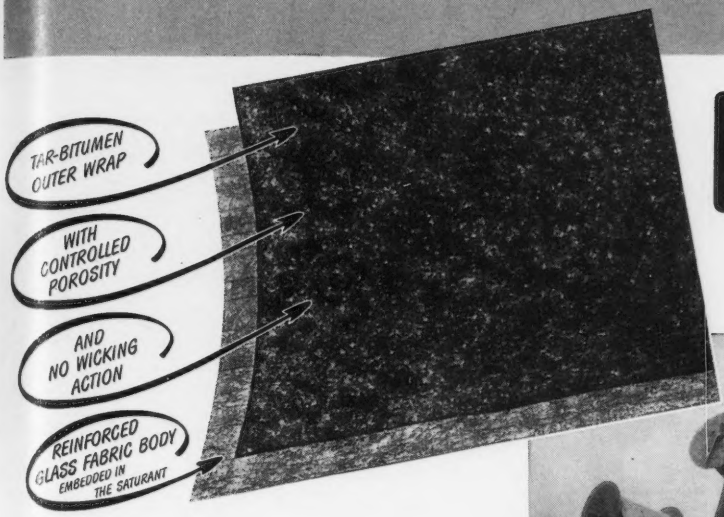
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AND NO WICKING ACTION
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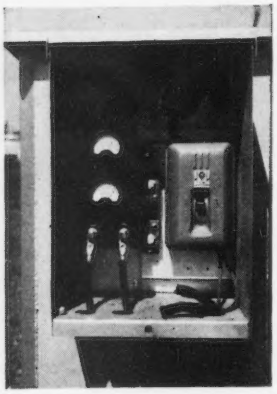
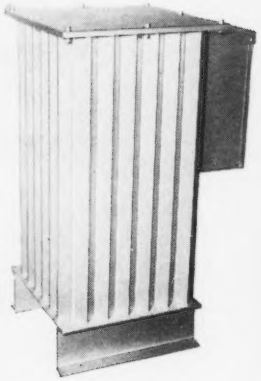
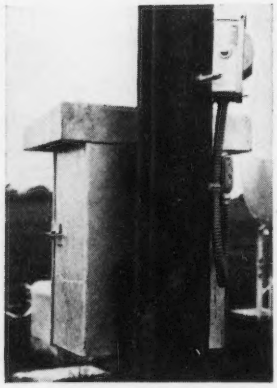
Cathodic Protection



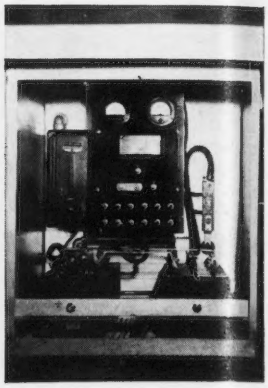
Oil-immersed, selenium rectifier —field installation showing meter and terminal box.



The NEW Westinghouse oil-immersed selenium rectifier—a 24V, 90 amp. unit just 43 inches high overall—36 gallons of oil suffice where 150 gallons were required in identical units of previous design.



Brance-Krachy air-cooled selenium rectifier in location showing pole mounting. (Method of connecting dc and ac leads optional.)



Typical unit construction—Brance-Krachy air cooled, selenium rectifier. Note sturdiness and easy accessibility.

OIL IMMERSED RECTIFIERS

Westinghouse selenium rectifiers have long been recognized for their quality featuring:

★ 11 ga. plate construction, bonderized—completely weather proof.

★ Large meter and terminal box easily accessible for making connections and reading meters.

★ AC circuit breaker equipped with heater type thermal overload relays.

★ Unitized construction of power unit for easy removal and inspection.

AIR-COOLED RECTIFIERS

New design features in Brance-Krachy air-cooled, selenium rectifiers are scaled to meet the demand for compactness and ruggedness in construction in this type of unit. These rectifiers are unsurpassed in quality, yet economical in terms of initial investment and years of trouble free performance. They feature:

★ 11 ga. plate construction—bonderized, or hot-dip galvanized after fabrication — case completely insect proof.

★ Fansteel selenium stacks—normally derated for operation at 60° ambient temperature for extra stack life.

★ AC starter—heater type overload protection.

★ Heavy duty transformer construction with strap type secondary top changer. We will build the unit to meet your requirements.

BRANCE-KRACHY *Cathodic Protection* RECTIFIERS

ADD VALUABLE YEARS OF LIFE AND SERVICE WITH B-K PACKAGED PROTECTION UNITS

Brance-Krachy complete package-type protection units include either copper oxide or selenium, air-cooled or oil-immersed rectifiers, underground "trench wire," graphite and carbon anodes and coke breeze backfill. Complete cathodic protection installations sent to your job as a unit. ALCOA magnesium anodes and M. C. MILLER'S MULTI-COMBINATION METERS in stock. We have all accessories for installing any type cathodic protection installation.

WE WILL BUILD THE UNIT TO MEET YOUR REQUIREMENTS

COMPLETE CATHODIC PROTECTION EQUIPMENT — BK

Brance-Krachy Co. INC.

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STAINLESS

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Some 30 alloy steels, each identified by its American Iron and Steel Institute number . . . able to thwart attacks by chemicals and atmospheres over a wide range of concentrations, pressures and temperatures...carry the family name "Stainless."

The addition of chromium in excess of 11% to steel provides, according to most generally accepted theory, a thin, adhering self-healing oxide film that protects the underlying metal. The result is a series of alloys highly resistant to corrosion and tarnishing in a wide variety of corrosive media.

Six per cent or more of nickel when added to chromium stainless steels produces a series of alloys of improved corrosion resistance known as the austenitic chromium-nickel stainless steels. Recognition by industry of this improvement is indicated by the fact that approximately two-thirds of all stainless steel tonnage produced is of the chromium-nickel type.

In the annealed condition austenitic chromium-nickel stainless steels are strong, tough, ductile and pliable. When cold-worked they are effectively strengthened and hardened; a tensile strength in excess of 200,000 p.s.i. is easily developed. Annealed, and even in the cold-worked condition, they are adaptable to many forming operations. In all conditions they are readily weldable.

At elevated temperatures, austenitic chromium-nickel stainless steels are distinguished by their strength and outstanding resistance to oxidation. At temperatures down to −300° F. they retain their toughness and unusual strength.

Other elements are sometimes added to give specific properties: to improve machinability, enhance scaling resistance, improve resistance to corrosion in specific, difficult cases.

Leading steel companies produce austenitic chromium-nickel stainless steels in all commercial forms. A list of sources of supply will be furnished on request.

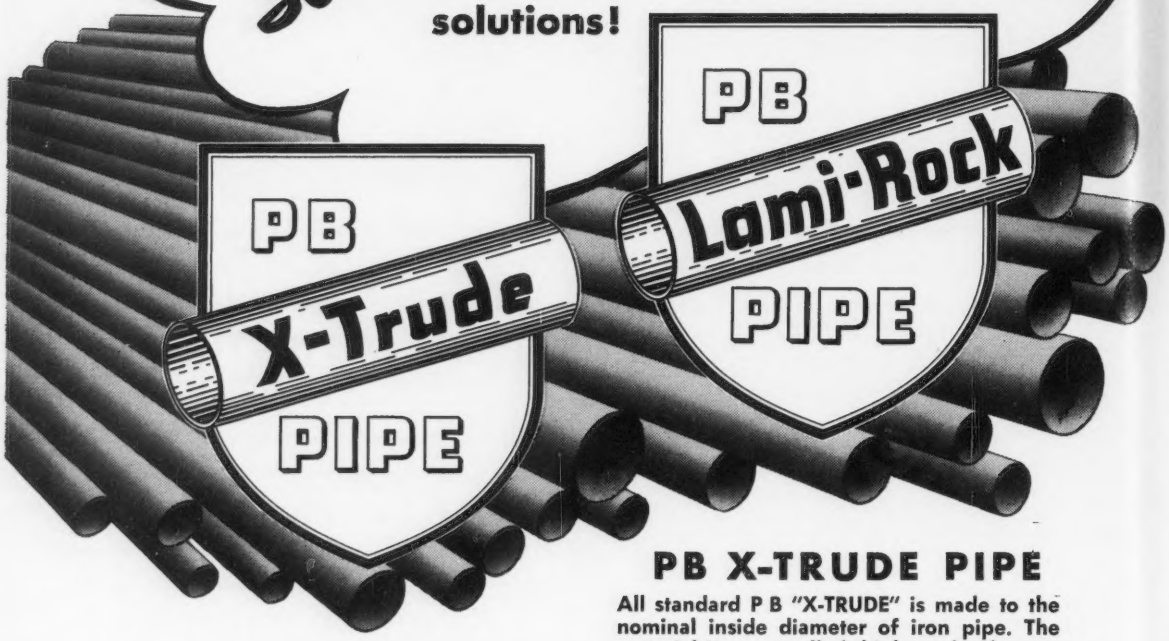
EMBLEM OF INCO SERVICE
TRADE MARK

Because of unusually heavy industrial and defense demand, rationing of nickel has been in force since July 1st. However, we believe that dissemination of technical data and service experience can help to promote the intelligent utilization of critical materials, so essential in these times. We shall, therefore, continue to issue information on new developments and user experience with nickel-containing materials.

THE INTERNATIONAL NICKEL COMPANY, INC.

so Light... can be laid by hand!

so Strong... will withstand highest pressure and most corrosive solutions!



For pipe so light that its per-foot freight rate is approximately 20% that of steel; for pipe that is non-corrosive and whose cold socket-weld method of joining excludes the possibility of leakage; for pipe with smooth walls and precision fittings that deliver a more even flow; for pipe of low maintenance cost, reduced storage and handling rates, increased volume or flow . . . insist on P B "X-Trude" and P B "Lami-Rock" pipe, that give you all these qualities, and more.

PB X-TRUDE PIPE

All standard P B "X-TRUDE" is made to the nominal inside diameter of iron pipe. The material is a controlled, high-grade, thermo-plastic extruded and cut into 20 foot tubes, size ½" to 2½" inclusive.

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All standard P B "LAMI-ROCK" pipe is made to the standard outside diameter of iron pipe. "LAMI-ROCK" is a controlled, high-grade thermo-setting plastic, reinforced with glass fibers cast into 20 foot pipe lengths. Each joint is pressure tested to four times its recommended operating pressure. Sizes 3" to 8" inclusive.

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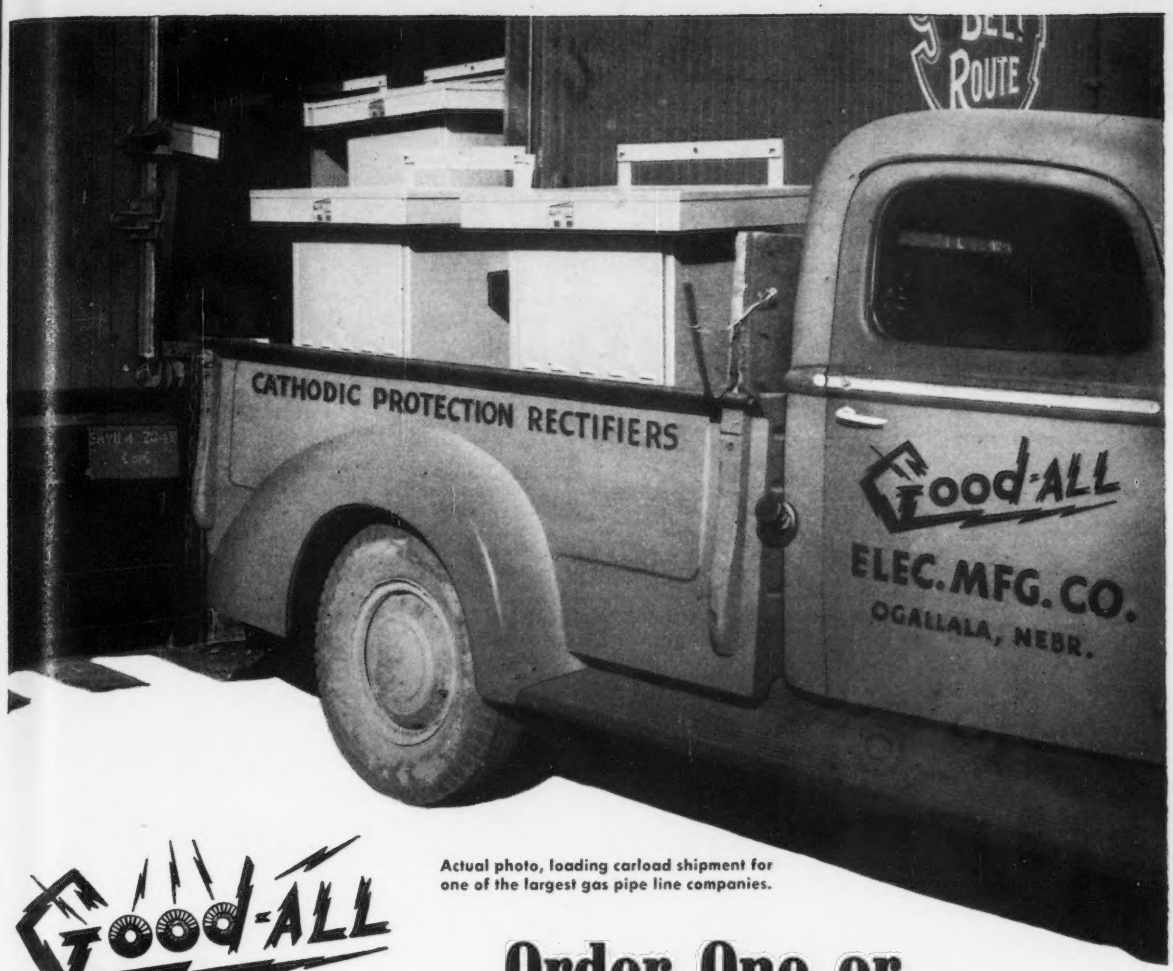

Actual photo, loading carload shipment for one of the largest gas pipe line companies.

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Cathodic Protection Rectifiers

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Ask about the new Good-All Hermetically Sealed Selenium Stacks

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The Good-All Rectifier is recognized as the leader by the world's largest gas pipe line companies. Several huge orders for Rectifiers have been awarded to Good-All.

The Good-All Cathodic Protection Rectifier guarantees the highest efficiency. You can select any combination D.C. volts or D.C. ampere output. Good-All is made in self, air-cooled models and oil-immersed, hermetically sealed models.

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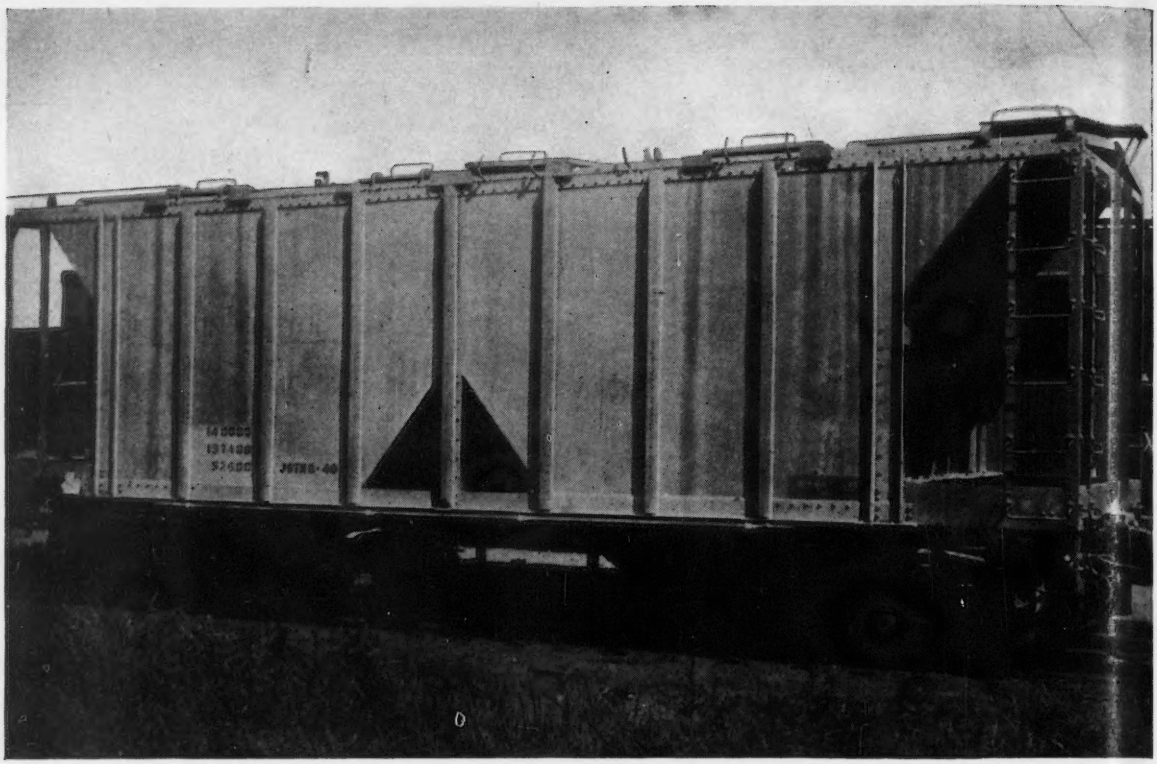

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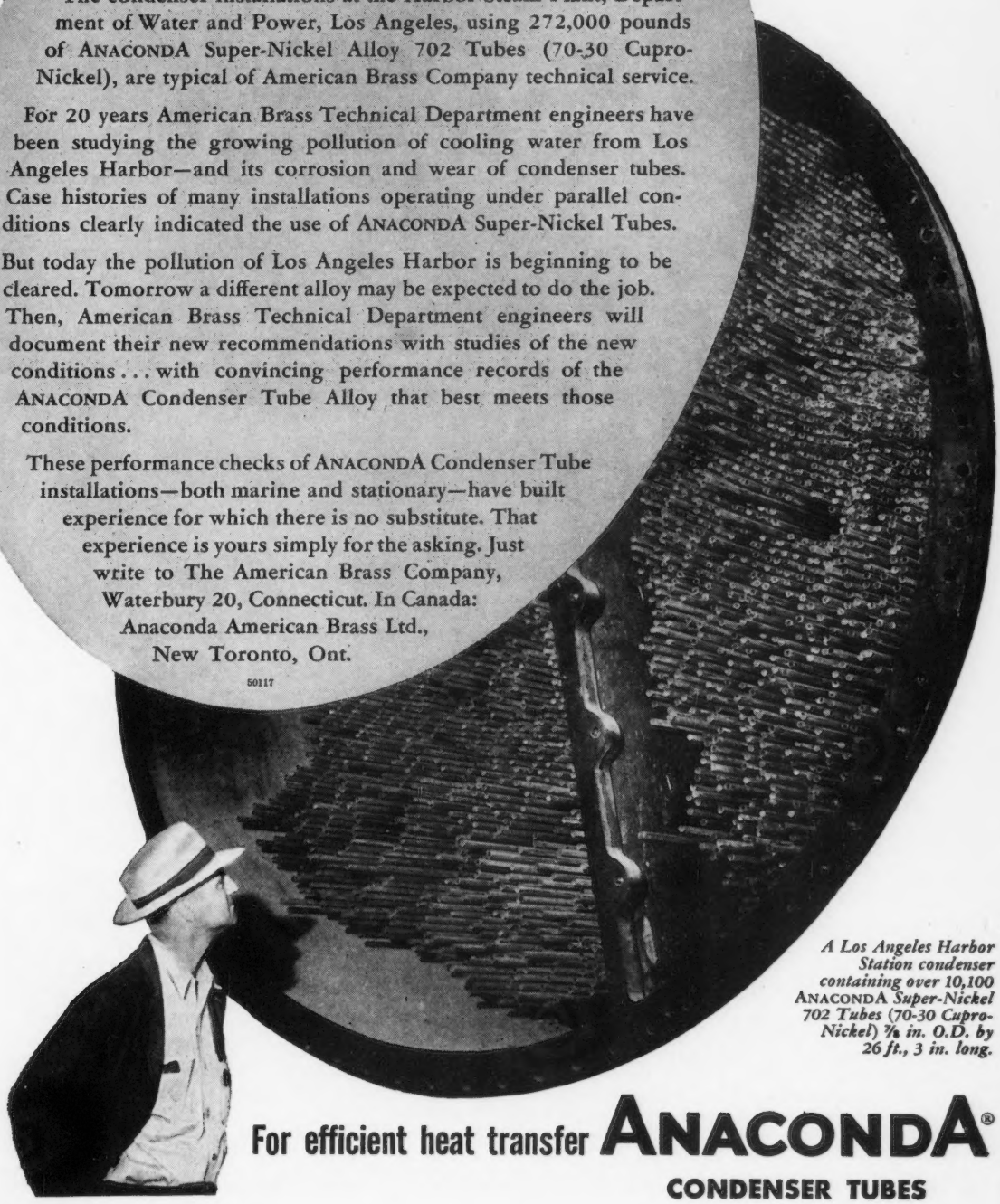

A Los Angeles Harbor Station condenser containing over 10,100 ANACONDA Super-Nickel 702 Tubes (70-30 Cupro-Nickel) ⅞ in. O.D. by 26 ft., 3 in. long.

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COVER EVERY PIPE-COATING NEED

1 **Pipeline Enamel**
2 **Millwrap Enamel**
3 **A.A. Enamel**
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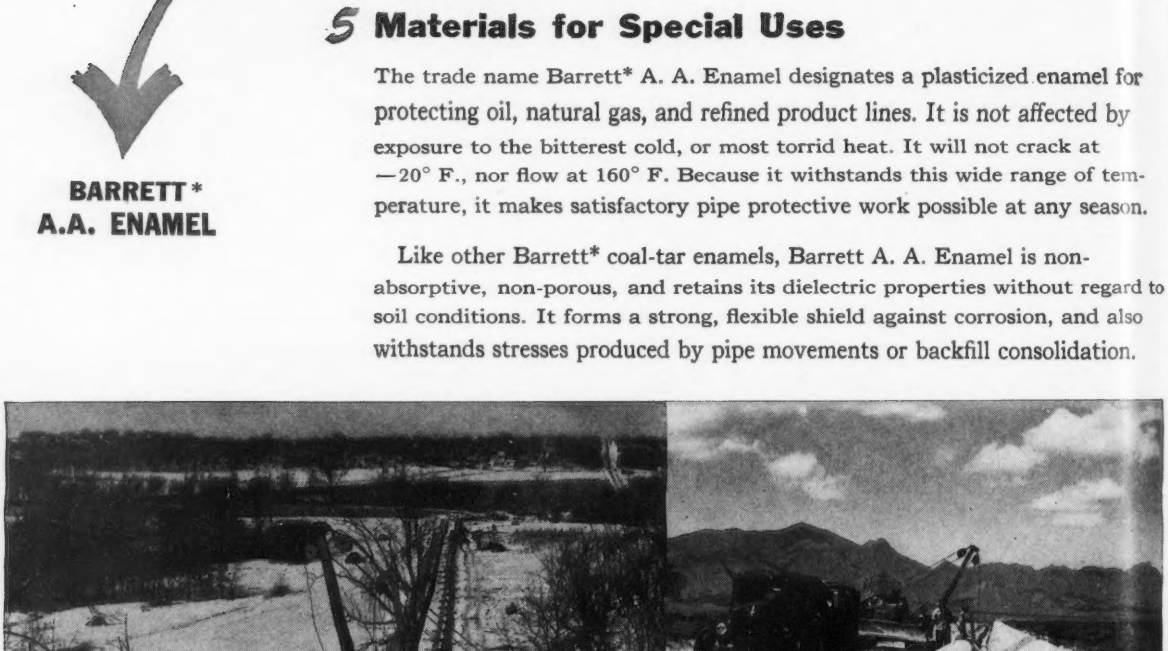
5 **Materials for Special Uses**

BARRETT* A.A. ENAMEL

The trade name Barrett* A. A. Enamel designates a plasticized enamel for protecting oil, natural gas, and refined product lines. It is not affected by exposure to the bitterest cold, or most torrid heat. It will not crack at —20° F., nor flow at 160° F. Because it withstands this wide range of temperature, it makes satisfactory pipe protective work possible at any season.

Like other Barrett* coal-tar enamels, Barrett A. A. Enamel is non-absorptive, non-porous, and retains its dielectric properties without regard to soil conditions. It forms a strong, flexible shield against corrosion, and also withstands stresses produced by pipe movements or backfill consolidation.



Above: Midwinter in Pennsylvania—Barrett A. A. Enamel will not crack at -20° F.
At right: Midsummer in the Arizona desert—Barrett A. A. Enamel will not flow, even at 160° F.

✓ *Memo:* FOR CORROSION ENGINEERS

Barrett coal-tar materials for special uses are all dependable, durable and economical. Eternium* Paint for exposed metal work. CA-50 Heavy-Duty Cold Application Coating for concrete and metal exposed to extremely corrosive conditions. Marine Enamel for ships, barges and off-shore service vessels. Service Cement and Pipeline Fabric for field joints—no torching required. Asbestos Pipeline Felt for soil stress shield. Tank Bottom Compound for sour crude storage. 34 YB Paint for exposure to salt water spray conditions.

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IMP

Technical Committee Activities

Objectives of Technical Practices Committee 1—Corrosion of Oil and Gas Well Equipment

By TED S. ZAJAC*

TECHNICAL PRACTICES Committee No. 1 was formerly known as the NACE Condensate Well Corrosion Committee. This earlier group was organized in 1944 to study the relative corrosion resistance of various metals and alloys in gas-condensate well service, with the objective of determining which classes of materials might give improved performance in the reference service. As the original work of the group was substantially completed by the latter part of 1948, the name of the committee was changed to that of its present title and its scope was considerably enlarged. In 1949, the committee was reorganized to improve its effectiveness and perpetuation, and now consists of the main group and seven sub-groups concerned with more or less specific projects of study. The chairman and vice-chairman of the parent group, and the chairmen of the sub-groups, also constitute a steering group which serves to guide the overall efforts of the committee.

The subject "Corrosion of Oil and Gas Well Equipment" is a broad and complex one, and covers a large number of costly problems related to the production of crude oil and natural gas. For the purposes of this committee, however, oil and gas well equipment is arbitrarily defined as that equipment needed to produce or control a well, covering only items of subsurface equipment but including the well head. Broadly speaking, TP-1 is interested in gathering and compiling definitive data on the seriousness and extent of the various corrosion problems related to oil and gas well equipment, and in assembling and compiling information on the different measures being used to control these problems. This general interest, of course, also includes the definition of the corrosive environments and the economics of the different control measures being used and tested. It is felt that TP-1 has made an excellent start toward achieving some of its general aims, however, considerable work remains to be done in the future. To those individuals and organizations who are concerned with the corrosion of oil and gas well equipment and its control, the committee extends its sincerest invitation to participate in its future studies.

TP-1 and its current subcommittees, with their scope of activities and memberships, are as follows:

Committee TP-1—Corrosion of Oil and Gas Well Equipment. Chairman: T. S. Zajac, Shell Oil Company, P. O. Box 2099, Houston, Texas. Vice Chairman: H. E. Waldrip, Gulf Oil Corporation, 5311 Kirby Drive, Houston, Texas.

Members:

T. S. Bacon, Lone Star Producing Company, Dallas, Texas.
J. P. Barrett, Stanolind Oil & Gas Company, 1136 N. Lewis Street, Tulsa, Okla.
H. L. Bilhartz, Atlantic Refining Company, P. O. Box 2819, Dallas, Texas.
Morris Bock, Sun Oil Company, P. O. Box 2280, Dallas, Texas.
R. C. Buchan, Humble Oil & Refining Company, P. O. Box 2180, Houston, Texas.
W. H. Edwards, The Texas Company, P. O. Box 425, Bellaire, Texas.
Kenneth Eilerts, U. S. Bureau of Mines, Bartlesville, Okla.
A. W. Galbraith, Babcock & Wilcox Tube Co., Houston, Texas.
E. C. Greco, United Gas Pipe Line Company, Shreveport, Louisiana.
H. J. Haynes, The California Co., P. O. Box 360, Natchez, Miss.
R. L. Hock, Cotton Valley Operators, Cotton Valley, La.
M. E. Holmberg, Phillips Petroleum Company, Bartlesville, Okla.
F. A. Hunter, J. S. Abercrombie Company, Drawer C., Sweeney, Texas.
J. Juppenlatz, Lebanon Steel Foundry, Lebanon, Pa.
E. O. Kartinen, Signal Oil & Gas Co., 811 W. Seventh St., Los Angeles, Cal.
V. V. Kendall, National Tube Company, Box 266, Pittsburgh, Pa.
H. T. Kennedy, A. & M. College of Texas, Mech. Eng. Dept., College Station, Texas.
J. P. Mallott, Continental Oil Company, Oil and Gas Bldg., Houston, Texas.
B. B. Morton, The International Nickel Co., 67 Wall St., New York, N. Y.
W. F. Oxford, Sun Oil Co., P. O. Box 2831, Beaumont, Texas.
F. A. Prange, Phillips Petroleum Company, Bartlesville, Okla.
R. J. Rice, The International Nickel Co., 1107 Commerce Bldg., Houston, Texas.
W. F. Rogers, Gulf Oil Corporation, Drawer 2100, Houston, Texas.
J. J. B. Rutherford, Babcock & Wilcox Tube Co., Beaver Falls, Pa.
Perry Spafford, Stanolind Oil & Gas Company, Gulf Bldg., Houston, Texas.
W. H. Speaker, Magnolia Petroleum Company, Magnolia Bldg., Dallas, Texas.

*Chairman TP-1. Shell Oil Corp., P. O. Box 2099, Houston, Texas.

W. H. Stewart, Sun Oil Company, San Jacinto Building, Beaumont, Texas.

R. S. Treseder, Shell Development Company, 4560 Horton St., Emeryville 8, Cal.

L. W. Vollmer, Gulf Res. & Dev. Co., P. O. Drawer 2038, Pittsburgh 30, Pa.

H. E. Waldrip, Gulf Oil Corporation, 5311 Kirby Drive, Houston, Texas.

J. W. Young, Imperial Oil Ltd., 300 9th Ave. W., Calgary, Alberta, Canada.

Scope:

This committee is interested in the broad subject of corrosion of oil and gas well equipment. In this regard, it is endeavoring to gather and compile definitive data on the environments causing oil and gas well corrosion, and the seriousness and extent of the various problems related to well equipment. It likewise is endeavoring to assemble and compile information on the various measures being used to control these problems. Where possible, the committee is also attempting to promote and correlate cooperative tests of materials in connection with the various problems. The committee's report covering the field testing of 32 metals and alloys in seven different gas-condensate fields is now in process of publication and should soon be available for distribution.

Subcommittee TP-1A — Corrosion of Oil and Gas Well Equipment (Pacific Coast). Chairman: E. O. Kartinen, Signal Oil and Gas Co., 811 West 7th St., Los Angeles, California.

Members:

J. A. Biren, The Texas Co., P. O. Box 320, Long Beach 1, Cal.

F. D. Bradbury, Kettleman North Dome Assn., Bin "C," Avenal, Cal.

J. J. Browne, General Petroleum Corp., P. O. Box 706, Wilmington, Cal.

R. W. Clark, Jr., Richfield Oil Corp., 555 South Flower, Los Angeles, Cal.

W. L. Crooks, Long Beach Oil Dev. Co., P. O. Box 199, Long Beach 2, Cal.

R. D. Dillard, Western Gulf Oil Co., P. O. Box 471, Bakersfield, Cal.

J. E. Gallagher, Shell Oil Co., 1008 W. 6th St., Los Angeles, Cal.

R. M. Gray, Long Beach Oil Dev. Co., P. O. Box 199, Long Beach 2, Cal.

P. M. Jorda, Shell Oil Co., 1008 W. 6th St., Los Angeles, Cal.

D. R. Knowlton, Kettleman North Dome Assn., Bin "C," Avenal, Cal.

J. C. Lynch, Richfield Oil Corp., 130 Pico, Long Beach, Cal.

H. J. Matthews, Union Oil Co., 17810 Central Ave., Compton, Cal.

D. M. McCloud, California Research Corp., P. O. Box 446, La Habra, Cal.

A. L. Mortimer, Standard Oil Co. of Calif., P. O. Box 397, La Habra, Cal.

W. S. Ostling, Signal Oil and Gas Co., 811 West 7th St., Los Angeles, Cal.

J. S. Romp, The Texas Co., P. O. Box "G," Fellows, Cal.

T. H. Shannon, Belridge Oil Co., McKittrick, Cal.

John R. Shore, Standard Oil Co. of Calif., 11-C Camp, Taft, Cal.

C. J. Smith, Western Gulf Oil Co., P. O. Box 471, Bakersfield, Cal.

Randolph Smith, Seaboard Oil Co., 612 South Flower St., Los Angeles 14, Cal.

Albert H. Tompkins, Jr., Chanslor-Canfield Midway Oil Co., 4561 Produce Plaza West, Los Angeles 11, Cal.

E. Thygeson, General Petroleum Corp., Prod. Dept., 2525 E. 37th St., Los Angeles, Cal.

R. J. Villagrana, Standard Oil Co. of Calif., P. O. Box 397, La Habra, Cal.

E. C. Yerby, Richfield Oil Corp., P. O. Box 470, Long Beach, Cal.

Scope:

This committee is interested in the broad subject of corrosion of oil and gas well equipment in the Pacific Coast petroleum producing area of the continental United States and keeps the parent committee advised of developments in the application of new methods and techniques introduced in that area. The committee is currently undertaking a study of corrosion in pumping oil wells in California, with emphasis on the following aspects: corrosion evaluation methods, use of alloy metals, use of mechanical coatings, use of inhibitors, and use of special gadgets.

Subcommittee TP-1B—Condensate Well Corrosion. Chairman: R. C. Buchan, Humble Oil & Refining Co., P. O. Box 2180, Houston, Texas.

Members:

C. M. Blair, Tretolite Co., 937 Pacific Ave., Webster Groves, Mo.

Morris Bock, Sun Oil Company, P. O. Box 2280, Dallas, Texas.

W. H. Edwards, The Texas Company, P. O. Box 425, Bellaire, Texas.

Kenneth Eilerts, U. S. Bureau of Mines, Bartlesville, Okla.

E. C. Greco, United Gas Pipe Line Co., Shreveport, La.

R. L. Hock, Cotton Valley Operators, Cotton Valley, La.

M. E. Holmberg, Phillips Petroleum Co., Bartlesville, Okla.

F. A. Hunter, J. S. Abercrombie Company, Drawer C, Sweeney, Texas.

E. F. Kelly, Dowell, Inc., 2115 Commerce Bldg., Houston, Texas.

F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.

R. J. Rice, The International Nickel Co., 1107 Commerce Bldg., Houston, Texas.

Perry Spafford, Stanolind Oil & Gas Co., Gulf Bldg., Houston, Texas.

W. H. Stewart, Sun Oil Co., San Jacinto Building, Beaumont, Texas.

H. E. Waldrip, Gulf Oil Corp., 5311 Kirby Drive, Houston, Texas.

E. W. Wallace, Shell Oil Co., P. O. Box 2099, Houston, Texas.

H. J. Haynes, The California Co., P. O. Box 360, Natchez, Mississippi.

Scope:

This committee is interested in the specific subject of high pressure gas-condensate well corrosion and is endeavoring to gather and compile data and information relative to this problem and its control. The committee is currently compiling data on the performance of alloys and coated (plastic and metallic) tubing, as well as data on the use and effectiveness of neutralizing and inhibiting chemical treatments.

Subcommittee TP-1C—Sweet Oil Well Corrosion. Chairman: H. L. Bilhartz, Atlantic Refining Co., P. O. Box 2819, Dallas, Texas.

Members:

R. C. Buchan, Humble Oil & Refining Co., Box 2180, Houston, Texas.

W. H. Edwards, The Texas Company, Box 425, Bellaire, Texas.

H. L. Haynes, The California Co., Box 360, Natchez, Miss.

W. F. Rogers, Gulf Oil Corp., Drawer 2100, Houston, Texas.

H. E. Waldrip, Gulf Oil Corp., 5311 Kirby Drive, Houston, Texas.

E. W. Wallace, Shell Oil Co., P. O. Box 2099, Houston, Texas.

Scope:

This committee is interested in the specific sub-

ject of high pressure sweet oil well corrosion and is endeavoring to gather and compile data and information relative to this problem and its control. The committee is currently compiling statistical data on this fairly new problem and will present a paper on its work to date at the Association's 1951 Oil and Gas Industry Symposium.

Subcommittee TP-1D—Sour Oil Well Corrosion. Chairman: New chairman being selected to succeed Mr. H. D. Murray, who recently returned to duty with the Armed Services.

Members:

Jack Barrett, Stanolind Oil & Gas Co., 1136 N. Lewis St., Tulsa, Okla.
Jack L. Battle, Humble Oil & Refining Co., Box 2180, Houston, Texas.
Leo Bell, Dia-Log Company, Box 3043, Odessa, Texas.
H. L. Bilhartz, Atlantic Refining Co., Box 2819, Dallas, Texas.
P. P. Blanda, Kewanee Oil Co., Box 838, Crane, Texas.
C. O. Bundrant, Western Company, Box 310, Midland, Texas.
J. A. Caldwell, Humble Oil & Refining Co., Box 2180, Houston, Texas.
Fred Converse, Stanolind Oil & Gas Co., Box 1540, Midland, Texas.
F. Lee Current, Oil Well Supply, Oil City, Penn.
Pat R. Donnelly, Tretolite Company, Box 1005, Midland, Texas.
R. L. Elkins, Shell Oil Company, Box 1509, Midland, Texas.
L. W. Folmar, The Texas Company, Box 1270, Midland, Texas.
E. C. Greco, United Gas Corporation, Shreveport, La.
Jack Hamilton, Gulf Oil Corp., Box 83, Crane, Texas.
Richard Lembeke, Cities Service Oil Corp., Tallant, Okla.
W. F. Oxford, Sun Oil Co., Box 2831, Beaumont, Texas.
F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.
J. C. Spalding, Jr., Sun Oil Co., Box 2880, Dallas, Texas.
H. E. Waldrip, Gulf Oil Corp., 5311 Kirby Drive, Houston, Texas.

Scope:

This committee is interested in the specific subject of sour oil well corrosion and is endeavoring to gather and compile data and information relative to this problem and its control. It currently is compiling preliminary data as to the seriousness and extent of this problem, along with methods of detection and control used on the problem.

Subcommittee TP-1E—Bimetallic Galvanic Corrosion in Oil and Gas Wells. Chairman: W. F. Rogers, Gulf Oil Corp., P. O. Drawer 2100, Houston, Texas.

Members: The members of TP-1 serve as this sub-committee.

Scope:

This committee is interested in studying and proving or disproving the existence and influence of bimetallic galvanic corrosion in oil and gas wells. The committee held a symposium on this subject at the Association's recent South Central Regional Meeting in Houston, Texas, on October 8-9, 1950.

Subcommittee TP-1F—Metallurgy of Oil and Gas Well Equipment. Chairman: V. V. Kendall, National Tube Co., P. O. Box 266, Pittsburgh, Pa.

Members:

T. S. Bacon, Lone Star Producing Co., Dallas, Texas.
Kenneth Eilerts, U. S. Bureau of Mines, Bartlesville, Okla.
J. Juppenlatz, Lebanon Steel Foundry, Lebanon, Pa.
E. F. Kindsvater, Phillips Petroleum Co., Bartlesville, Okla.
B. B. Morton, International Nickel Co., Inc., 67 Wall St., New York 5, N. Y.
F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.
L. W. Vollmer, Gulf Research & Development Co., P. O. Drawer 2038, Pittsburgh 30, Pa.

Scope:

This committee is interested in all metallurgical problems related to oil and gas well equipment. This group played an important role in the study of metals and alloys in gas-condensate wells. It currently is available to serve in an advisory capacity to any of the other TP-1 sub-groups while studying several possible future projects for investigation.

Subcommittee TP-1G—Sulfide Corrosion Cracking. Chairman: R. S. Treseder, Shell Development Co., 4560 Horton Street, Emeryville 8, Cal.

Members:

A. C. Broyles, Carter Oil Company, Tulsa, Okla.
F. A. Prange, Phillips Petroleum Co., Bartlesville, Okla.
L. W. Vollmer, Gulf Research & Development Co., P. O. Drawer 2038, Pittsburgh 30, Pa.

Scope:

This committee is interested in the problem of sulfide corrosion cracking as occurs in high pressure sour gas-condensate wells and other corrosive sour fluids. The committee has just completed compiling preliminary known information on this problem and is currently expanding its membership and effort in anticipation of tackling more specific phases of the problem.

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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A Preliminary Investigation

Control of Corrosion by Salt Used for De-Icing Highways*

By JOHN A. TEMMERMAN and AARON STERLIN

IN RECENT YEARS municipal authorities have been concerned with a problem arising from the use of salt for street and highway snow and ice removal. Complaints of damage to fenders, bodies and frames of automobiles, claimed to be caused by the salt, went beyond the nuisance stage. For example, the protests to the Akron, Ohio, city officials during 1944 were of sufficient intensity to compel the authorities to take immediate action. The City of Rochester, N. Y., likewise heard annual complaints from its citizens regarding the use of salt. This situation came to a head on Janaury 13, 1948, when about 2000 automobile owners petitioned the city and demanded that salt should not be used for street deicing purposes.

However, during the years between 1944 and 1948, both communities had been investigating the possibility of using an additive to inhibit salt corrosion. Late in 1947, the City of Akron, acting on the recommendation of the Goodyear Rubber Company Research Division, began using sodium dichromate as a salt additive. In Rochester, the City Laboratory had begun an independent research program in 1945 to find a means of alleviating the corrosion due to salt. Although several materials gave favorable results, the city was unable to obtain sufficient quantities of any of the desired additives.

It was in August of 1948 that, through the intervention of the International Salt Company, a cooperative research program was instituted between the City of Rochester and the National Aluminate Corporation in an attempt to find a readily available material to be used as a salt additive. An inhibitor, to be satisfactory and safe for use on city streets, must be nontoxic, non-staining and non-irritating to the skin. Further, it must prove harmless to rubber, leather and various types of clothing.

Of the materials contemplated, chromate-base inhibitors, although tested, were not considered due to their toxicity.[1,2] There remained consideration of a number of materials, such as phosphates, nitrites, etc., and various water-soluble organic salts reported as being effective corrosion inhibitors. Salts of nontoxic, poly-valent metals were investigated for possible use in combination with the corrosion inhibiting materials.

*A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

JOHN A. TEMMERMAN, city chemist for the City of Rochester, N. Y., whose principal fields of research are in forensic and municipal problems, holds a BS in chemical engineering from Catholic University, Washington, D. C., and has done post-graduate work at the same institution as well as extension work at the University of Rochester and the Rochester Institute of Technology.

AARON STERLIN, a chemist with National Aluminate Corporation, Chicago, Ill., has been with this company since his graduation with a BS in chemistry from Roosevelt College of Chicago in 1948. His work has been with various types of corrosion problems. He is a member of ACS.

Abstract

The use of salt for ice and snow control on streets and highways has caused some concern on the part of municipal officials with respect to increased corrosion of automobile bodies. A cooperative program was undertaken which resulted in the development of a polyphosphate nitrite base inhibitor. Laboratory tests indicated it was effective in controlling corrosion by salt brines. Procedures used in the testing as well as the results obtained are presented. Weight loss data on mild steel panels are given as a function of inhibitor and salt concentrations. Finally, the experience of the City of Rochester, N. Y., using the above inhibitor incorporated in rock salt, are discussed.

It was recognized that a testing procedure must be devised which would be simple in nature and would require a minimum of laboratory equipment so that it could be used by municipal operators whose laboratory facilities might not be too extensive. The procedure consisted of an immersion test adaptable to the evaluation of a proposed material in a relatively short time.

Specimens of 22-gauge mild steel, 2¾ x 5⅞ inches, were selected for use in the tests. As received, they were oiled and corrosion free, requiring only degreasing in trichloroethylene vapors before use. Tests conducted at various immersion times showed that one overnight immersion in a 25.0 percent by weight

salt brine containing the additive as 2.0 percent of the salt, would serve as a satisfactory means of screening the various inhibitors. This procedure was an accelerated corrosion test wherein it was possible to tell after one overnight immersion whether the additive being tested would be effective. As a result of these tests, a polyphosphate-nitrite base formula, containing a strontium salt, was developed which proved effective under these conditions. This inhibitor, a product of the National Aluminate Corporation, became known as Nalco No. 818-C.

After the initial series of tests, during which time the effectiveness of this inhibitor was established, further testing was indicated in order that the optimum concentration could be determined. Information regarding its effectiveness at brine concentrations lower than the one tested was likewise desired. For this purpose, the tests were to be evaluated by weight loss. The panels used previously were adopted for these tests with the following modifications in handling being made. First, the specimens were weighed to the nearest 0.1 milligram after being degreased and second, an area, 1 x 2¾ inches at one end of the panel was dipped in paraffin to protect the specimen from waterline corrosion. This latter precaution was required since the tests were conducted in one-liter beakers where the depth of liquid did not permit complete immersion of the specimen. The ratio of surface area of a panel to volume of test solution was one square decimeter (dm^2) to about 675 ml of brine. The solutions were prepared with distilled water using rock salt, rather than the refined material, to make the brine. Various concentrations of brine were tested both with and without the inhibitor.

The original testing procedure of one overnight immersion was modified to include one 3-hour and one 17-hour immersion separated by drying periods of two hours' duration. The procedure was repeated for five days so that the weight loss of an individual specimen would be of a measurable magnitude. The cleaning method consisted of immersing the specimen for 30 seconds in 18° Baumé muriatic acid inhibited with 0.06 percent by weight of thiourea. After pickling, it was dipped in a 10 percent soda ash solution, rinsed in running water and then wiped dry. Prior to weighing, the panels were degreased in toluene to remove any remaining traces of paraffin from the specimen. This procedure was repeated until no further weight loss, other than that due to acid attack, could be found. A correction was applied to the weight loss to compensate for losses due to acid attack of the metal. This was determined by cleaning an uncorroded specimen in the manner described.

After evaluation of the tests, the following conclusions were reached. The tests conducted at various brine concentrations (Figure 1), showed that an inhibitor concentration of 1.0 percent is effective in brines containing over 9.0 percent sodium chloride by weight. In the 25.0 percent brines, an inhibitor concentration of 0.5 percent decreases the corrosion due to salt by 90 percent.

When the inhibitor concentration was held constant while the brine content varied (Figure 2), the reduction in the corrosion rate was greatest at the 1.0 percent inhibitor concentration. It was noted that in all cases where the inhibitor was used, the 1.0 percent was more corrosive than the 3.0 percent brine.

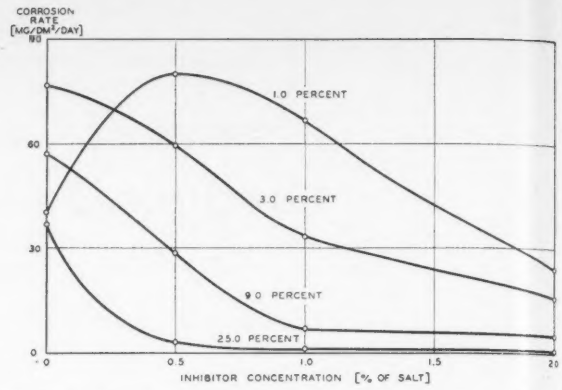

Figure 1—Corrosion rate at constant brine concentration. Five-day alternate immersion.

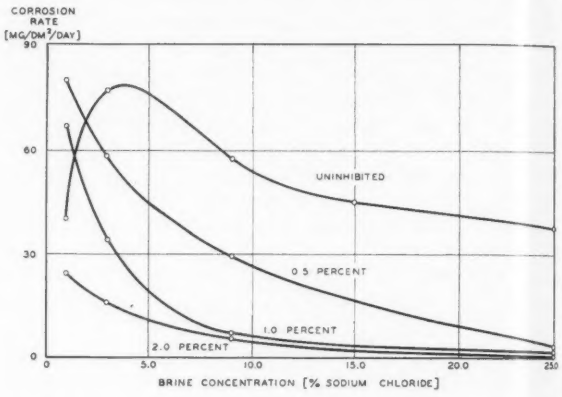

Figure 2—Corrosion rate at constant inhibitor concentration. Five-day alternate immersion.

The conclusion of the laboratory work did not, in any way, establish the complete effectiveness of the inhibitor, since information as to its effectiveness under actual conditions was still lacking. A program of field testing was undertaken using specimens like those used in the laboratory experiments, only modified to permit their being mounted on the chassis of an automotive vehicle. The City of Rochester, N. Y., where the inhibitor was being used with rock salt, was selected as the principal test area. For the comparison of results between Rochester and other areas in the same climatic zone, municipalities using salt only, as well as others where no ice removal measures were being used, were selected. The vehicles chosen for this experiment, conducted during the 1948-49 winter, included passenger cars, trucks and snow plows.

When the panels were removed in the spring and subsequently cleaned, it was found that the information obtained was not as clear-cut as was desired. The individual weight losses of some specimens within a given group varied widely. However, an

average of the corrosion rate for a group of specimens showed that, where the inhibitor was used, the corrosive action of the salt had been reduced. The deviations found were to be expected, because data obtained in other fields, where corrosion test panels were used, showed similar variations. It must be considered that an experiment of this type is influenced by a number of factors, many of them beyond human control. The realization that these uncontrollable variables exist, shows the necessity of extending this program over a longer time. In this way a sufficient number of specimens would be collected, thereby permitting a statistical analysis to be conducted. Although the final criterion still depends on the ability of the inhibitor to arrest the corrosion of the fenders and body of the vehicle itself, the use of a corrosion panel permits a more exact evaluation not based on appearance, but on the specimen's weight loss.

A program of testing, using the corrosion test panel, would be of value to a group of cities interested in this problem. It would permit the standardization of the test method, in that uniform mounting and location of the panel on the vehicle would be attained, as well as the acquisition of a consistent preparation and cleaning method. A central agency should be selected, from the participating group, to assemble and correlate the data obtained in this program. This would then permit the comparison of corrosion rates from areas where no salt is used and where salt alone is used, with those obtained from localities using salt with an inhibitor. It must be recognized that the installation of one or two test panels in a given area would not give any information adaptable to a statistical analysis. Proper sampling can be obtained when a minimum of 40 specimens are used in a given locality. This program, extended over a number of years, would yield the information required for proper evaluation of an inhibitor's effectiveness.

However, the experience of the City of Rochester, N. Y., during the 1948-1949 and 1949-1950 winter seasons, while using this inhibitor, must be mentioned. In Rochester, where from four to seven times the amount of salt used in most other cities of comparative size is spread on the streets, not a single complaint was registered by the local automobile club or a private individual, as compared to the winter of 1947-1948 when the petition was received. It has also been brought to the attention of the investigators that somewhat similar results were obtained in Akron, Ohio, where a polyphosphate-type inhibitor was incorporated with the salt.

References

1. H. B. Elkins, The Chemistry of Industrial Toxicology, John Wiley and Sons, Inc., New York, 1950, p. 69.
2. F. A. Patty, Industrial Hygiene and Toxicology, Interscience Publishers, Inc., New York, 1949, p. 692.

DISCUSSION

Comment by G. M. Magee, Research Engineer, Association of American Railroads, 3140 S. Federal St., Chicago 16, Illinois:

This paper is interesting to us because of the work we have done on adding an inhibitor to salt used in icing refrigerator cars for the protection of the track and bridge structures from brine drippings. Our earlier work indicated that sodium dichromate neutralized with soda ash was very effective for this purpose, but we did not consider it advisable to use this inhibitor in general operation because of its toxicity. Recent work has indicated that sodium polyphos will prevent the corrosion almost as effectively without the disadvantage of toxicity. A somewhat different procedure was used in removing the corrosion from the test specimens in our work, and this method may be of interest to some. In our tests the specimens were cleaned of rust in hot 10% ammoniacal solution of ammonium citrate before weighing.

Discussion by F. L. LaQue, International Nickel Co., Inc., New York:

In considering the effect of salt on the corrosion of steel automobile bodies, special consideration should be given the important effect of the humidity of the atmosphere in which the automobiles operate or are stored (garaged). This becomes complicated by the hygroscopic effect of salt accretions in permitting corrosion to continue when salt-free surfaces would be dry. In some tests with which the author of this discussion is familiar, but which have not been published, the humidity of the garage atmosphere appeared to be more important than the salt treatment of roads in determining the extent of corrosion of the automobile bodies.

To provide an idea of the magnitude of the corrosive effects with which we are concerned here, the author of this discussion has incorporated data kindly furnished by one of the authors of the paper—Mr. J. A. Temmerman—in a table which is appended here.

It will be observed that even without any inhibition of corrosion by de-icing salt, the extent of corrosion was only three to four times that resulting from exposure to the atmospheres in the cities where salt was used, and only about one-third that ex-

Results of Corrosion Tests on Steel Panels Attached to Automobiles Driven Over Roads With and Without Salt Treatment and Exposed to Corrosion in Different Atmospheres and Salt Spray Boxes.

City	Tons Salt Used on Roads per 100,000 Population	Rate of Corrosion of Steel in Inch Penetration per Year
A*	3,500†	0.0040
B*	500	0.0062
C*	None	0.0046
A*	Atmospheric Exposure Only	0.0012
B*	Atmospheric Exposure Only	0.0015
C*	Atmospheric Exposure Only	0.0027
X	Atmospheric Exposure 80 ft. from Ocean at Kure Beach	0.020
Y	Corrosion in 3% Salt Spray	0.041
Z	Corrosion in 20% Salt Spray	0.015

* Unpublished data from J. A. Temmerman, City Chemist, Rochester New York.
† 1 to 2% Polyphosphate Type Inhibitor Added to Salt.

perienced by steel exposed to the atmosphere close to the ocean or in conventional salt spray cabinets.

The corrosion of automobile bodies was discussed in greater detail in a paper by E. J. Hergenroether and the writer presented at the June 1949 meeting of the Society of Automotive Engineers, French Lick, Indiana. Those interested may wish to refer to this paper as well.

Discussion by Marc Darrin, Mutual Chemical Company of America, 1348 Block Street, Baltimore 31, Maryland:

I am pleased to hear of the good results obtained at Rochester with de-icing salts inhibited with a nitrite preparation. The discussion has brought out that under some conditions such as the presence of calcium or magnesium chloride, another type of inhibitor might be required. Chromate is the only inhibitor known to be effective in calcium chlorine brines. As you know it is a very powerful inhibitor, effective in comparatively small amounts, but Mr. Temmerman has ruled out its consideration because of toxicity.

Now I would not want to subject anyone to danger, but the fear of chromate is due largely to lack of knowledge. To the best of my knowledge no one in this country has died of chromate poisoning within the past hundred years. It takes a high dosage to kill small animals. The comparatively dilute solutions used for corrosion protection are not very dangerous since rats are not harmed by drinking water containing 500 ppm over long periods of time.[1] Chromate appears to be non-cumulative and quickly eliminated.

Mr. Temmerman mentioned that dogs may lap up rather large amounts of salty ice water from the street. On the basis of reported tests[1] with rats and mice, it is not reasonable to believe that a dog could drink at one time sufficient chromate-containing brine to have a harmful effect. I would also like to call to your attention that much higher concentrations have been employed for years in refrigerating brines and their use is recommended by the American Society of Refrigerating Engineers, in both calcium and sodium chloride brines.[2]

The purpose of my comments on this subject is not to minimize possible hazards but to view them in a proper perspective. Of course I urge precautions in handling strong solutions and solids. Avoid breathing the dust, and keep it out of cuts or your eyes. Do not allow it to remain in contact with the skin; wash it off with plenty of water. About the same precautions apply to the handling of most chemicals.[3]

A related subject brought out by discussions from the floor is an inhibitor for dilute calcium chloride solutions at normal temperature. Contrary to what might be expected dilute solutions are more aggressive than strong brines. No inhibitor is completely effective, however sodium chromate is sufficiently effective to be satisfactory for most purposes, and to the best of my knowledge is the only inhibitor commonly employed for this purpose. As the concentration of the calcium chloride is increased the effectiveness of the inhibitor increases. A strong calcium chloride solution such as is used in refrigerating actually requires less chromate than a sodium chloride brine.[2] No known inhibitor will protect against a hot calcium chloride solution. These remarks apply to completely submerged ferrous surfaces, either aerated or non-aerated. Galvanized surfaces behave in about the same manner. Contact with cathodic metals makes protection difficult. Other important factors are relative areas, movement of liquid and its pH.

References

1. W. G. Gross and B. G. Heller, "Chromates in Animal Nutrition," *J. Ind. Hygiene & Tox.*, p. 52-56 (1946). March.
2. American Society of Refrigerating Engr., Cir. 10, p. 3 (1930); Marc Darrin. "Chromate Corrosion Inhibitors in Brine Systems." ASRE 1944 Corrosion Report, p. 21-27.
3. Marc Darrin. "Corrosion Inhibition with Chromate," *Oil & Gas J.*, p. 83 (1949). Jan. 13.

DISCUSSIONS ARE INVITED

Readers who wish to submit written information additive to articles published in CORROSION, or who wish to register differences of opinion with respect to any articles are urged to send such discussions to Dr. F. N. Alquist, Chairman, NACE Editorial Review Committee, Organic Research Laboratories, 20A Building, Dow Chemical Co., Midland, Mich. Doctor Alquist will submit such discussions to a member of the review committee, and after review and approval the discussion will be published.

The expression of opinions about or the addition of information to that contained in technical articles will advance the interests of NACE and make CORROSION more valuable to the membership.

Some Applications of Electrochemical Thermodynamics*

By MARCEL POURBAIX

A. Theory

1. *Electrochemical Reactions—Reaction Potential and Equilibrium Potential*

Figure 1 illustrates an experimental isothermal apparatus which consists of one side of an electrochemical system (1.2), on the electrode of which the electrochemical reaction occurs:

$$\Sigma \nu M + ne = 0 \qquad (1$$

that is to be considered, for example:

$$Fe = Fe^{++} + 2e$$

$$2Cl^{-}_{aq} = Cl_2 + 2e$$

$$Mn^{++}_{aq} + 4H_2O = MnO^{--}_{4aq} + 8H^{+}_{aq} + 5e$$

and on the other side of a reference electrochemical system (3.4) (reversible reference electrode) in which the state of thermodynamic equilibrium of a reference electrochemical reaction is realized.

$$\Sigma \nu' M' - ne = O \qquad (2$$

for example: $2H^{+}_{aq} + 2e = H_2$ (Hydrogen Reference Electrode)

Connect the solutions 2 and 3 by means of an electrolytic capillary siphon of the Haber-Luggin type which does not produce a diffusion potential, and which passes into the solution 2 in the immediate vicinity of the electrode 1. Join the two electrodes 1 and 4 by means of a potentiometric apparatus which is connected with these electrodes by means of two conductors established on the same metal 5. Indicate by E′ and E, respectively, the potentials of electrode 1 in relation to electrode 4: on one hand in the general case in which the affinity of the reaction 1) is not zero; on the other hand in the particular case in which this affinity is zero (that is to say when the system 1.2 is in thermodynamic equilibrium), the reactive chemical constituents in both cases being at the same temperature, the same concentration or activity if they are in the dissolved state, or the same pressure or fugacity if they are in the gaseous state.

(E′ shall be called the *reaction potential* and E the *equilibrium potential* of reaction 1).

The value of E can be calculated thermodynamically if the free energies of formation (or the molecular chemical potentials) of the different reactive substances are known, for example, by means of the formula

*Translated from Atti Convegno Associazione Italiana di Metallurgia, Milano, Italia, pp 8-24, May 1948.

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Abstract

The affinity and velocity of an electrochemical reaction, the magnitude and sign of which can be measured are discussed with consideration of all the electrochemical phenomena which can take place on the same metallic surface. The study is facilitated by the knowledge of the polarization curves. This treatment is applied to the behavior of iron in the presence of aqueous solutions (behavior of electrically insulated and non-insulated iron; influence of oxidizing agents upon the potential and upon the speed of corrosion, etc.) These principles also have been applied to a fundamental study of the reactions between hydrogen and some oxidizing substances on a platinum surface, which was published by Wagner and Traud in 1938.

$$E = \frac{\Sigma \nu \mu}{23{,}060} \qquad (3$$

in which the "molecular chemical potentials" μ are expressed in calories, and in which the potential E is expressed in volts.

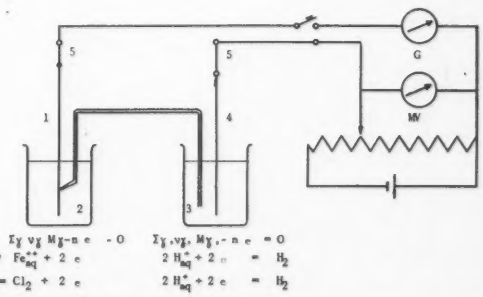


Figure 1—Experimental apparatus for the study of electrochemical reactions.

2. *Affinity of the Electrochemical Reactions—Overvoltage.*

It can be shown that the affinity of reaction (1 can be expressed in magnitude and sign by the formula

$$A = E' - E \text{ (in volts per Faraday}^3\text{)}$$

a demonstration of which has been given by Prigogine.[4]

If overvoltage*(x) of the electrochemical reaction is defined as being equal in magnitude and sign to this difference E′ — E between the reaction potential and the equilibrium potential of the reaction, the conclusion is reached that "the affinity of an electrochemical reaction can be measured in magnitude and sign by the value of its overvoltage."

3. *Velocity of the Electrochemical Reactions.*

The velocity of an electrochemical reaction can be measured in magnitude and sign by the strength *i* of the "electric reaction current" which corresponds to it according to the equation of the reaction, and which expresses the velocity of liberation of the electric reaction charges

$$v = i \quad (4$$

This current *i* is regarded as positive when the electrochemical reaction takes place in the form of an oxidation, and it is regarded as negative when the reaction occurs in the form of a reduction.

4. *Direction of the Electrochemical Reactions.*

De Donder has stated[7] that in the case of a chemical reaction the direction in which the reaction takes place is related to the sign of the affinity of this reaction by the relation

$$A \times v \geqslant O \quad (5$$

which means that the velocity v of a chemical reaction is always either zero or of the same sign as its affinity, A.

If this relation is applied to the case of the electrochemical reactions, and if it is taken into account that

$$A = E' - E \quad (3$$

and that

$$v = i \quad (4$$

the relation is obtained

$$(E' - E)\ xi \geqslant O, \quad (6$$

which means that the reaction current *i* of an electrochemical reaction is always either zero or of the same sign as the overvoltage of this reaction.

The result is that an electrochemical reaction can take place only in the form of an *oxidation* if its overvoltage is *positive*, that is, if the reaction potential E′ of the surface on which the reaction occurs is higher than the equilibrium potential E of this reaction. An electrochemical reaction can take place only in the form of a *reduction* if its overvoltage is *negative*, that is, if the reaction potential E′ is lower than the equilibrium potential E.

5. *Polarization Curves.*

From the practical viewpoint it is convenient to represent the influence of the reaction potential E′ upon the direction and velocity of the electrochemical reactions by means of such a diagram as Figure 2, in which the reaction potential E′ (measured by means of a Haber-Luggin siphon) is represented on the ordinate and the reaction current *i* is represented on the abscissa.

All the *oxidation reactions*, for which the current *i* is positive, will be represented on the right of the axis of the ordinate. All the *reduction reactions*, for which *i* is negative, will be represented on the left of this axis. The relationship

$$(E' - E)\ xi \geqslant O \quad (6$$

which connects the direction of the electrochemical reactions with the sign of their overvoltage implies that, with such a manner of representation, the polarization curves relative to all the electrochemical reactions are inclined in the same direction (rising from left to right) and that these curves pass through a point which is situated on the axis of the ordinate and for which both affinity and reaction velocity are zero.

This is true for any metal on the surface of which the reaction takes place and it makes no difference whether this surface is the site of a single reaction or of several simultaneous reactions. This results especially in the following two important consequences:

1. The direction in which a given electrochemical reaction can occur upon a metallic surface does not depend *per se* on the nature of the metal,

* This definition of overvoltage is in agreement with one proposed in 1939 by Eyring, Glasstone and Laidler[5]. If it is so defined, overvoltage corresponds to what Lange and Nagel called "Fehlspannung[6]" in 1937.

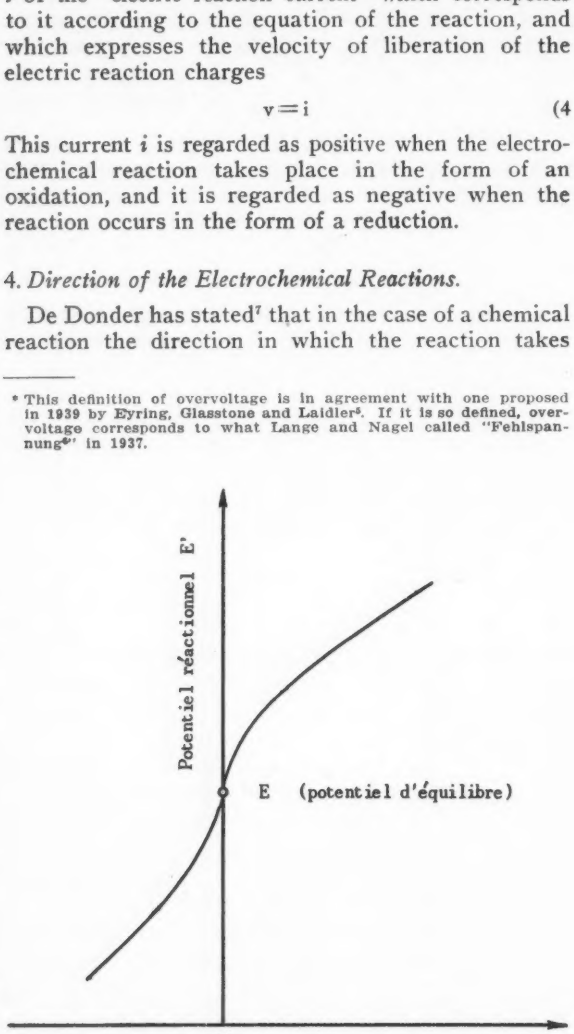


Figure 2—Polarization curve.

but solely on the value E′ of the potential of the metal measured with Haber and Luggin's method.* Whatever this metal may be, the speed of reaction will be zero if the potential E′ of this metal is equal to the equilibrium potential E of the reaction.

2. The simple superposition on the same diagram of the polarization curves representing the different electrochemical reactions which can be produced on the same metallic surface will afford a picture of the circumstances under which these reactions can occur simultaneously on this surface.**

The aspect of polarization curves can vary, as indicated in Figure 3, according to the degree of irreversibility of the reactions:

In the case of strongly irreversible reactions the reaction velocity will remain practically at zero for perceptible affinity values. That is, the polarization curve will remain practically identical with the axis of the ordinate for reaction potentials which are different from the equilibrium potential E.

On the contrary, in the case of practically reversible reactions a slight affinity will be sufficient to permit the reaction taking place with noticeable speed, that is the polarization curve will deviate from the axis of the ordinate when the reaction potential deviates from the equilibrium potential.

The reactions of dissolution and electrochemical precipitation of the "normal" metals (for example, Cd, Hg and Pb) according to Piontelli's conception, present polarization curves of the first type, which especially implies the effective realization of the states of thermodynamic equilibrium, a slight polarization and the easy realization of the concentration cells.[11, 12, 13]

B. Applications†

It is interesting to examine some experimental applications of this thermodynamic conception of electrochemical phenomena with respect to the corrosion of metals.

The behavior of iron in the presence of an aqueous solution and a study by Wagner and Traud on the reaction between hydrogen and some oxidizing substances on platinum will be considered.

1. *Behavior of Iron in Presence of an Aqueous Solution.*

Consider the case of an iron electrode in contact with gaseous hydrogen under one atmosphere pressure and which immersed in an aqueous solution with pH = 4 containing 0.01 gram ion of iron per liter (in the form of ferrous ions, Fe^{++}).

Figure 4a and 4b represents the diagram of equilibrium of the system Fe-H_2O at a temperature of 25 degrees C.[1,2]

In this figure the pH of the solution is represented on the abscissa and the equilibrium potential of the various possible electrochemical reactions on the ordinate. The acid media and the alkaline media are situated respectively on the left and right sides, and the oxidizing media and reducing media respectively in the upper and lower parts.

Water is stable thermodynamically under a pressure of one atmosphere only in the region included between the line rH = O (along which it is in

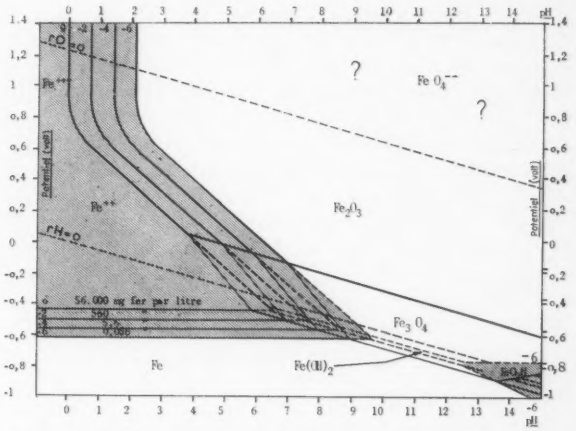


Figure 4a—Equilibrium diagram of the system Fe-H_2O at 25 degrees C. [For a Fe_2O_3 the solubility product of which has the value $(Fe^{+++}) \cdot (OH)^3 = 10^{-42.0}$]

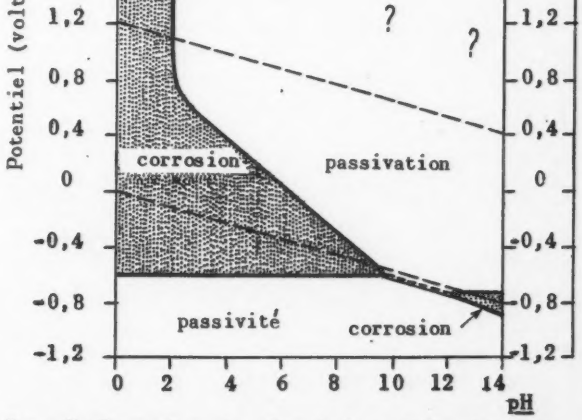


Figure 4b—Zones of corrosion, of passivation and of passivity of iron.

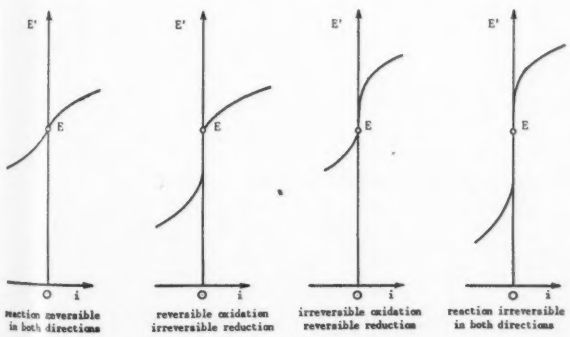


Figure 3—Different types of polarization curves.

* In 1898 Haber expressed a similar opinion.[8] Independently Lange and Nagel dealt with the influence of the potential in 1937 and 1938.[8, 9]

** In 1938 Wagner and Traud applied this method to the study of corrosion.[10]

† Some accounts of this subject have been given in other publications.[14, 15, 16]

equilibrium with hydrogen under one atmosphere) and the line $rO = O$ (along which it is in equilibrium with oxygen at one atmosphere).* Below the line $rH = O$ water tends to decompose with liberation of hydrogen and with alkalinization; above the line $rO = O$ water tends to decompose with liberation of oxygen and with acidification.

Figure 4a indicates that in the shaded regions iron can exist in solution and can do so in a concentration which becomes stronger the greater the departure from the borders of these regions. As is well known, the green ferrous ion Fe^{++} is stable in a reducing and noticeably acid or neutral medium. The brown ferric ion is stable in a relatively oxidizing and acid medium. The green dihypoferric ion FeO_2H^- is stable in a reducing and very alkaline medium.

In the unshaded regions of Figure 4a iron and its oxides are practically insoluble. Metallic iron is stable only under very reducing conditions on account of which water tends to decompose with formation of hydrogen. In presence of oxygen Fe_2O_3 is stable. In the small central zone some $Fe(OH)_2$ can be formed which is thermodynamically unstable in relation to magnetite Fe_3O_4 and which tends to convert into the latter substance.

If for the purpose of establishing a pattern it is assumed a solution is or is not corrosive with respect to iron according to whether the quantity of iron it tends to dissolve is larger or smaller than 10^{-6} gram atom per liter (i.e. 0.056 mg/l) the assumption follows that the contour relative to this content separates regions in which corrosion is possible from those in which it is impossible. Therefore, this diagram involves two zones in which there is corrosion and one in which there is no corrosion.

Figure 4b, which shows these zones, gives a synthetic picture of the circumstances under which iron is corroded and of those under which it is not. According to a proposal of G. Chaudron, in the zone in which there is no corrosion, a place can be distinguished in which the surface of iron is in a really metallic state and where there will be *passivity*, from another place in which the iron is covered with a protecting film of oxide and in which there will be *passivation*.

The corrosion of the iron by the usual solutions is a result of the fact that in the middle of Figure 4b there is a large "dangerous triangle" and that it is in this area that the representative point of the system iron/solution usually is located. In order to protect iron against corrosion this point may be moved down, up or to the right.

The technique of cathodic protection of iron structures by means of electricity or by means of zinc or magnesium reactive anodes proceeds by lowering the potential. The action of an oxidizing agent always causes an increase of the potential. Accordingly, it will increase or suppress corrosion according to whether the potential becomes stable in the corrosion zone or in the passivation zone. When iron is used as an electrolytic anode, which raises its potential, the emission of a current brings about corrosion of the metal if the current is under a low potential, by far the most general case; but this emission can take place without corrosion if the current emitted is under a high potential.

A strong alkalization of the solution will cause suppression of corrosion provided the solution contains an oxidizing substance. In the absence of an oxidizing agent, the zone is one in which slight corrosion occurs, but which becomes more important if the alkali content and the temperature rise. It is this zone which often is the origin of that type of boiler corrosion called "caustic embrittlement."

Figure 4 especially means that metallic iron and water, as is well known, cannot be stable simultaneously. The system they form can be the site of two electrochemical reactions:

$$Fe = Fe^{++} + 2e \qquad (a$$

$$\text{and} \quad H_2 = 2H^+ + 2e \qquad (b$$

the equilibrium potentials of which are, respectively —0.50 volt and —0.24 volt referred to the standard hydrogen electrode.

The first of these reactions can occur only in the direction

$$Fe \rightarrow Fe^{++} + 2e \qquad \text{(Oxidation)}$$

or in the direction

$$Fe^{++} + 2e \rightarrow Fe \qquad \text{(Reduction)}$$

according to whether the potential of the metal surface is higher or lower than —0.50 volt. The speed of the reaction will vary as a function of this potential, as indicated by curve A of Figure 5 according to which a current strength equal to one ampere corresponds to the transformation of 0.289 mg of iron per second.*

1. *Case of Iron Electrically Insulated.*

In case the iron is electrically insulated the potential must be such there is neither emission or absorption of the current. The strength of the positive current relative to the oxidation reaction must be equal to the strength of the negative current relative to the reduction reaction. In order that this condition may be realized, according to Figure 5 the iron must have a potential of —0.42 volt.

In this case the iron will be the site of the oxidation reaction

$$Fe \rightarrow Fe^{++} + 2e$$

under an overvoltage equal to

$$-0.42 + 0.50 = +0.08 \text{ volt}$$

and of the reduction reaction

$$2H^2 + 2e \rightarrow H_2$$

under an overvoltage equal to

$$-0.42 + 0.24 = -0.18 \text{ volt}$$

* $r_O = -\log p_{H_2}$
$r_O = -\log p_{O_2}$ and $rH = -\log p_{H_2}$
where p_{O_2} and p_{H_2} are respectively the equilibrium pressures in oxygen and in hydrogen (measured in atmospheres).

* One Faraday (i.e. 96,540 amperes x seconds) corresponds to the transformation of 27.92 g of iron or of 1.00 g of hydrogen.

These two reactions occur with equal speed and opposite signs and lead to the aggregate reaction

$$Fe + 2H^+ \rightarrow Fe^{++} + H_2$$

which in a well known manner expresses the usual corrosion of iron in acid solutions.

If the electrically insulated metallic surface can be the site of more than two electrochemical reactions, the rule which establishes the value of the potential is the same as that which has been expounded in the case of two electrochemical reactions: the potential will have such a value that the sum of the oxidation current equals the sum of the reduction currents.

If, for instance, the solution with pH = 4 which has just been considered contains an oxidizing substance such as dissolved oxygen which is susceptible of reduction according to the aggregate reaction

$$2\,O_2 + 4H^+ + 4e \rightarrow 4\,OH^- \qquad (c$$

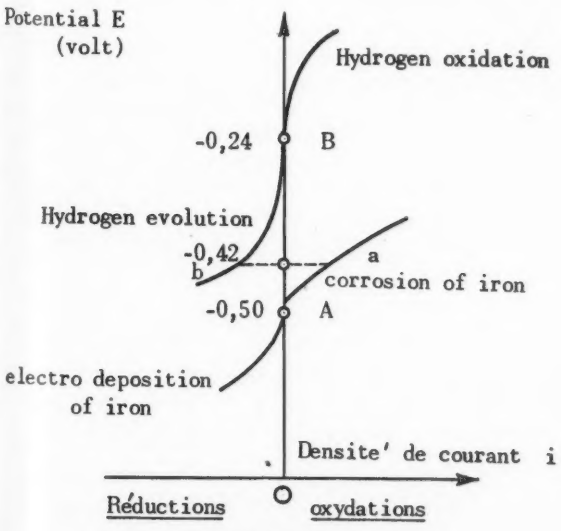
the presence of this oxidizing substance will be manifest in Figure 5 through the existence of a supplementary polarization curve c in Figure 6 which will express the influence of the potential on the speed of this reduction reaction.

Figure 6 shows that in this case the effect of the presence of the oxidizing substance is to raise the potential of the metal and increase the velocity of its corrosion.

2. Case of Iron Not Electrically Insulated

If the iron is not electrically insulated, but is used as an electrolytic anode or cathode, it must take such a potential that the algebraic sum of the oxidation currents and reduction currents relating to the different possible electrochemical reactions is equal to the electrolysis current, in amount and sign.

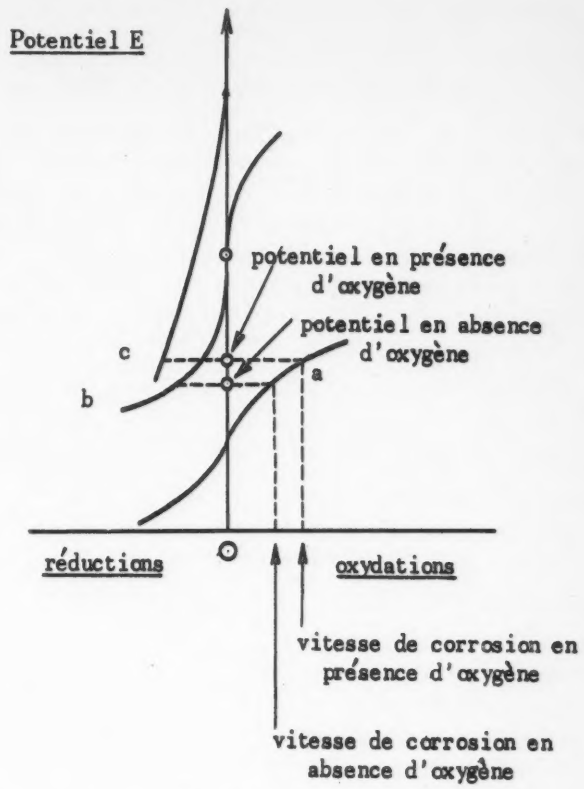
This can be illustrated by the previous case which



$$Fe \rightleftharpoons Fe^{++} + 2\,e \qquad (a)$$

$$H_2 \rightleftharpoons 2\,H^+ + 2\,e \qquad (b)$$

Figure 5—Behavior of iron in acid solution without oxidizing substances. (Polarization curves.)

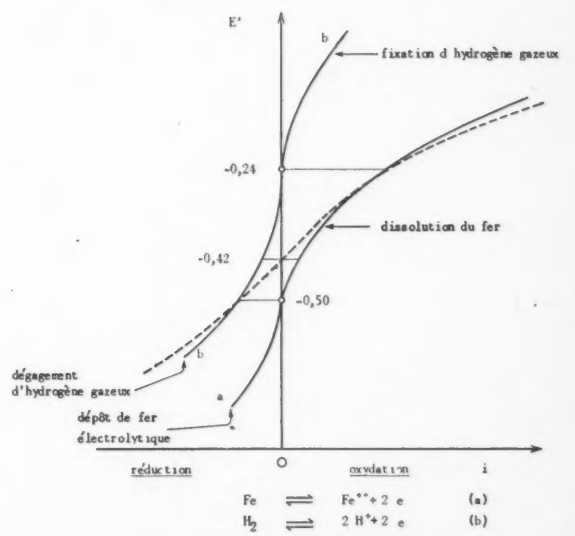


$$Fe \rightleftharpoons Fe^{++} + 2\,e \qquad (a)$$

$$H_2 \rightleftharpoons 2\,H^+ + 2\,e \qquad (b)$$

$$4\,OH^- \rightleftharpoons O_2 + 2\,H_2O + 4\,e \qquad (c)$$

Figure 6—Behavior of iron in acid solution containing oxygen. (Polarization curves.)



$$Fe \rightleftharpoons Fe^{++} + 2\,e \qquad (a)$$

$$H_2 \rightleftharpoons 2\,H^+ + 2\,e \qquad (b)$$

Figure 7—Behavior of iron utilized as an electrolytic anode or cathode (in acid solution free of oxidizing substances). (Polarization curves and electrolytic current.)

is represented in Figure 5 by an iron electrode which is in contact with gaseous hydrogen under a pressure of one atmosphere and which is immersed in an aqueous solution with pH = 4 containing 0.01 gram ion of Fe^{++} per liter.

It has been noted already that if the iron is electrically insulated it will have a potential of —0.42 volt and will be the site of the aggregate reaction

$$Fe + 2H^+ \rightarrow Fe^{++} + H_2$$

With this iron as an electrolytic *anode* an increase in the potential of the metal will be produced, a potential which will vary as the function of the strength of the electrolysis current according to the broken line indicated in Figure 7. In proportion to the increase of potential of the iron and until the surface of the iron will remain really metallic (that is until the reaction (a) is possible) there will be produced an increase in the speed of corrosion according to the reaction

$$Fe \rightarrow Fe^{++} + 2e \qquad \text{(Curve a}$$

and a decrease in the speed of liberation of hydrogen according to the reaction

$$2H^+ + 2e \rightarrow H_2 \qquad \text{(Curve b.}$$

When the potential reaches the value of —0.24 volt (equilibrium potential of reaction b) the speed of this reaction will be zero. If the potential continues to increase and if the hydrogen atmosphere around the anode is maintained by means of an external supply, this reaction will change in direction and the metal will be the site of the two simultaneous reactions

$$Fe \rightarrow Fe^{++} + 2e \qquad \text{(Corrosion}$$

and $$H_2 \rightarrow 2H^+ + 2e \qquad \text{(Fixation of gaseous hydrogen}$$

the velocities of which are respectively represented by the curve *a* and the curve *b*.

With iron as an electrolytic *cathode*, rather than an anode, the potential of the metal will take a value lower than —0.42 volt. In proportion to the decreasing potential of the iron there will be produced an increase in the speed of hydrogen liberation according to the reaction

$$2H^+ + 2e \rightarrow H_2 \qquad \text{(Curve b}$$

and a decrease in the speed of corrosion according to the reaction

$$Fe \rightarrow Fe^{++} + 2e \qquad \text{(Curve a}$$

When the potential reaches —0.50 volt (equilibrium potential of the reaction $Fe = Fe^{++} + 2e$), the speed of this reaction will become zero. If the potential continues to decrease this reaction will change direction and the metal will be the site of the two simultaneous reactions

$$Fe^{++} + 2e \rightarrow Fe \qquad \text{(Deposit of electrolytic iron}$$

and $$2H^+ + 2e \rightarrow H_2 \qquad \text{(Liberation of gaseous hydrogen}$$

the velocities of which are represented by curves *a* and *b* respectively.

3. *Behavior of Iron at High Voltage*

The reactions *a* and *b* involve four substances: Fe, Fe^{++}, H_2 and H^+. The equilibrium diagram 4 shows that in the presence of the solutions mentioned there can be formed also other substances, especially magnetite (Fe_3O_4) and ferric oxide (Fe_2O_3) which can be more or less hydrated.

Experience shows that these two substances really are formed under these conditions. Nevertheless while Fe_3O_4 appears in the form of a porous covering, Fe_2O_3 stands at the surface of the metal as a protecting non-porous film* which by removing metallic iron from contact with the solution makes impossible the occurrence of the corrosion reaction

$$Fe \rightarrow Fe^{++} + 2e \qquad \text{(a}$$

As a result of this there is produced a deep modification of the reaction system because of the lack of equilibrium which then exists between the strength of the electrochemical reactions and the strength of the eventual electrolytic current. The potential of the iron increases abruptly at the moment passivation appears and it tends to become stable with a new value for which this lack of equilibrium will disappear.

If iron is employed as an electrolytic anode the potential rises until a new oxidation reaction becomes possible with a speed corresponding to the strength of the electrolytic current. In the case represented in Figure 8, for example, the potential will become stable at point (1) which is located above the equilibrium potential of the reaction

$$4OH^- = 2O_2 + 4H^+ + 4e \qquad \text{(c}$$

and the passivated anode will be the site of liberation of oxygen according to the reaction (c.

If the increase in the potential of the iron derives not from the use of the metal as an electrolytic anode but from the reaction of an oxidizing substance dissolved in the solution, the potential will take a value for which the algebraic sum of the reaction oxidation and reduction currents will be zero. If no oxidation reaction is possible, the potential will be such that the speed of the reduction of the oxidizing substance is zero, for example, in region 2 in Figure 8. Moreover, if this reduction reaction of the oxidizing substance is reversible, the potential will equal the equilibrium potential of this reduction reaction, that is, the oxidation reduction potential of the solution.

It may be repeated that the "passivation potential" of iron is the equilibrium potential of the system Fe^{++}/Fe_2O_3,**[1] that is, the equilibrium potential of the reaction.

$$2Fe^{++} + 3H_2O = Fe_2O_3 + 6H^+ + 2e \qquad \text{(d}$$

It is important to note that this potential depends only on the physicochemical state of the reactive substances, that is, that for a given oxide Fe_2O_3 it

---

* Where there are not appreciable quantities of chlorides (and other halides) in solution.

** That equilibrium potential is given approximately by the formula: $E = 0.75 - 0.177\ pH - 0.059 \log (Fe^{++})$, at 25 degrees C.

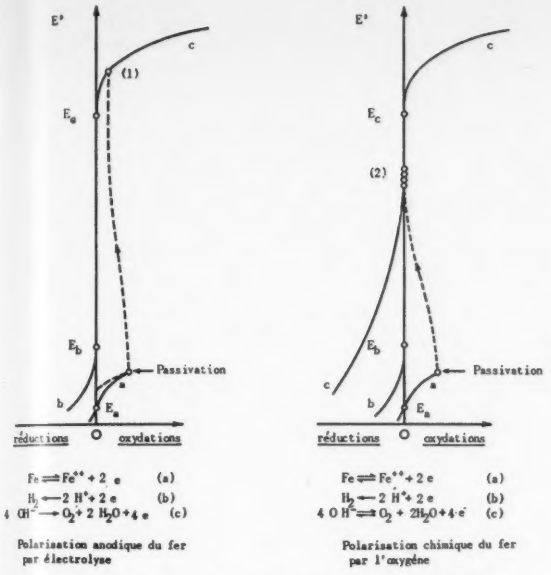


Figure 8—Influence of voltage on the behavior of iron.

depends on the temperature, pH and activity of Fe^{++} ions of that portion of the solution in immediate contact with the metal. This potential does not depend at all on the route taken to reach it. The result is that, under equal temperature, pH and iron content of that portion of the solution in contact with the metal, the passivation of the iron by formation of a film of Fe_2O_3 will appear for the same value of the potential whether this passivation is realized electrochemically (by anodic polarization) or chemically (by dissolution of an oxidizing substance in the solution).

4. *Representation as a Whole of the Behavior of Iron Used as an Electrode*

The result of the previous discussion is that, for a given physicochemical state of each one of the reactive substances, the direction of each one of the electrochemical reactions that can take place on a metallic surface is closely related to the value of the potential of this surface. This potential is measured in relation to a reversible control electrode in which the siphon for connection with the solution passes into the latter in the immediate vicinity of the metallic surface.

For each one of these electrochemical reactions the speed will be zero when the potential of the surface is equal to the equilibrium potential of the reaction. Each one of these reactions can occur only in the direction of an oxidation or in the direction of a reduction, according to whether the potential of the surface is higher or lower than the equilibrium potential, and the reaction speed will be related to the value of the overvoltage of the reaction in accordance with what is expressed by the respective polarization curves.

These considerations permit the graphical representation of all forms of behavior of iron used as an electrode in a solution free of oxidizing substances

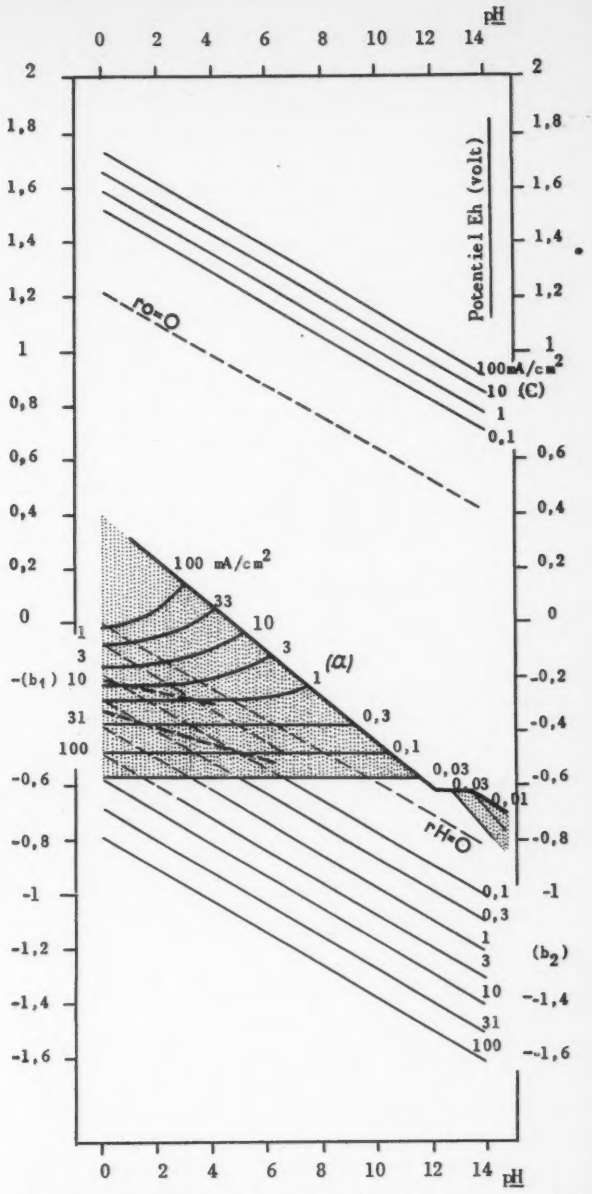


Figure 9—Representation as a whole of the behavior of iron used as an electrode.

by means of Figure 9 in which have been traced lines according to which each one of the three reactions

$$Fe \rightarrow Fe^{++} + 2e \quad \text{(a}$$

$$2H^+ + 2e \rightarrow H_2 \quad \text{(b}$$

$$\text{and } 4OH^- \rightarrow 2O_2 + 4H^+ + 4e \quad \text{(c}$$

occurs with a determined speed which corresponds to a current strength ranging from 0.03 to 100 milliamperes per cm.^{2}

In tracing this figure consideration has been given to the case of solutions practically free of iron, for which the equilibrium potential of reaction (a is located slightly below the two lines (a) marked 0.03. The equilibrium potentials of reactions (b and (c and represented by lines $rH = 0$ and $rO = 0$ respectively.

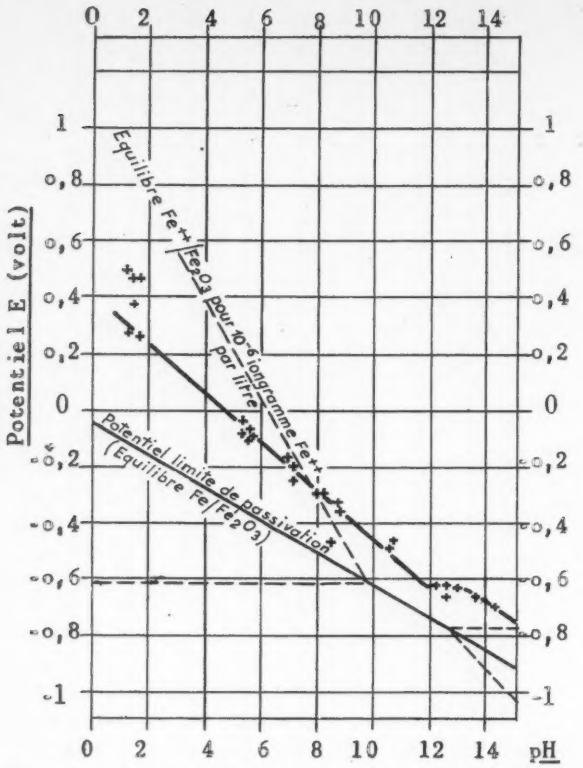

Potentiel E (volt)
pH
Equilibre Fe++ / Fe2O3 pour 10-6 ionogramme Fe++ par litre
Potentiel limite de passivation (Equilibre Fe/Fe2O3)

Figure 10—Influence of pH on the potential of anodic passivation of iron.

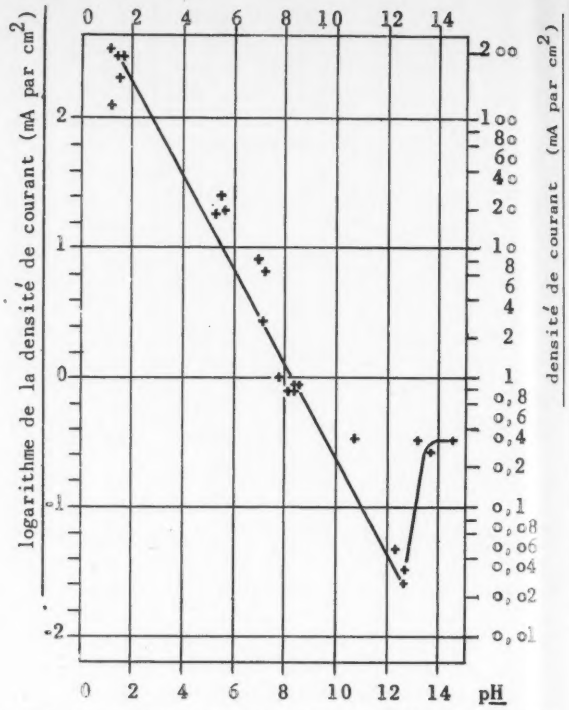


Figure 11—Influence of pH on the current strength of anodic passivation of iron.

It has been assumed the overvoltages relating to these reactions show the following values respectively for different current densities.*

TABLE A

i (mA/cm²)	Sa (v)	Sb₁ (v)	Sb₂ (v)	Sc (v)
0.1	+0.14	.....	—0.18	+0.30
1.0	+0.33	—0.08	—0.38	+0.37
10	+0.52	—0.28	—0.58	+0.44
100	.....	—0.48	—0.78	+0.51

It also has been assumed the passivation of iron appears for voltages and current strengths the values of which depend on pH as indicated in Figures 10 and 11.

The shaded region of Figure 9 indicates the circumstances under which the reaction (a can occur, that is, the circumstances under which there is corrosion of the iron.

C. Wagner and Traud's Experiments Relating to the Reaction Between Hydrogen and Some Oxidizing Substances on Platinum.

In 1938 Wagner and Traud described the following experiment, the importance of which is fundamental[10]:

A platinum electrode lightly coated with platinum black and saturated with gaseous hydrogen and two silver/silver chloride electrodes are immersed in a HSO_4^-/SO_4^{--} buffer solution which consists of water, Na_2SO_4 and HCl and which is placed in a closed vessel under one atmosphere, the pressure of which can be measured by a manometer (See Figure 12). Wagner and Traud performed the three following operations:

1. They measured the potential of the hydrogen electrode (indicated by Eg′) in relation to one of the Ag/AgCl electrodes.
2. Having added an oxidizing substance to the solution they observed a rise in the potential of the platinum (up to a value indicated by Em) as well as a certain speed of consumption of gaseous hydrogen.

Three tests were made, utilizing as oxidizing substances successively persulfate $K_2S_2O_8$, nitrobenzene $C_6H_5NO_2$ and arsenic acid H_3AsO_4 (mixed with arsenious anhydride).

3. By using the second Ag/AgCl electrode as an anode for each one of these three oxidizing substances, they finally cathodically polarized the platinum electrode in such a manner that its potential was brought back to the value Eg′ it had in stage 1 of the experiment when the solution was free of oxidizing substances. They kept this potential as constant as possible for some time and observed that neither consumption nor formation of gaseous hydrogen occurred.

Wagner and Traud observed the following values on the one hand for the increase in potential $E_m - E_g'$ in

TABLE B

Oxidizing Substance	E — E′ m h (Volt)	Speed of Fixation of H_2 for E — E_m (Equivs./sec.)	Current Strength for E — E_g' (milliamperes)
$K_2S_2O_8$	0.60	7×10^{-9}	6.4
$C_6H_5NO_2$	0.36	1.2×10^{-9}	1.7
H_3AsO_4	0.32	0.6×10^{-9}	0.005 to 0.5

* For the reaction (b relating to liberation of hydrogen on iron there has been considered two cases b_1 and b_2 relating respectively to a pickled iron surface with low overvoltage and to a polished iron surface with high overvoltage.

stage 2 of the experiment and on the other hand for the current strength which is necessary in stage 3 to bring the potential back to its initial value Eg′.

These experiments prove, as is established by electrochemical thermodynamics, that the speed of the reaction $H_2 = 2H^+ + 2e$ is really zero in presence of a metal the potential of which is equal to the equilibrium potential of this reaction and that this is true whatever method is used to realize this potential (the same conclusion could be reached by acting on metals other than platinum even if these metals can be corroded by the solution). During the third operation described above, the cathodic polarization of the platinum, although it produced an increase in the speed of reduction of this oxidizing agent, brought the speed of reduction of this oxidizing substance by the hydrogen back to zero. The reduction entirely a consequence of the action of the hydrogen for the potential E_m, has become merely electrolytic for the potential Eg′.

Note that results of these tests allow determination of four points established in Table C below of the polarization curve related to the reaction $H_2 \rightarrow 2H^+ + 2e$ in presence of the platinum black-coated platinum electrode which has been used for these experiments if, as is probable, this curve is not noticeably modified by the presence of an oxidizing substance. For the calculation of current strength it has been assumed a current of one milliampere corresponds to the oxidation of 10.4×10^{-9} equivalent of hydrogen per second, and familiar symbols are used as follows

$E_m = E'$ (reaction potential

$E_g' = E$ (equilibrium potential of the reaction $H_2 = 2H^+ + 2e$

i = strength of reaction current

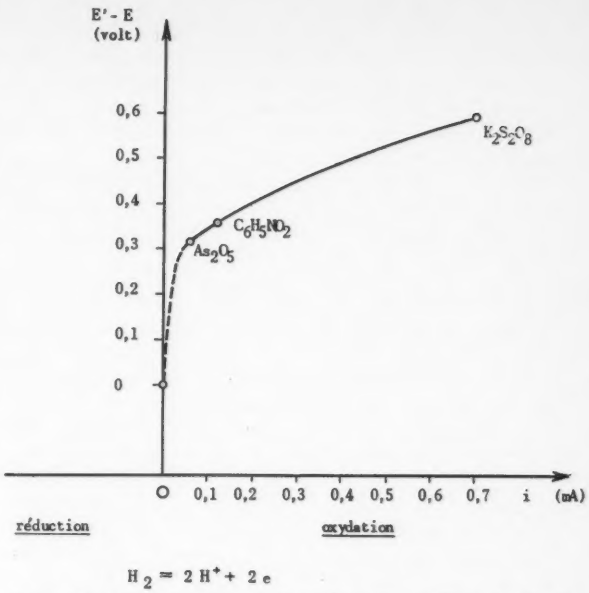


Figure 13—Polarization curve of the reaction $H_2 \rightarrow 2H^+ + 2e$. (In the case of Wagner and Traud's experiments.)

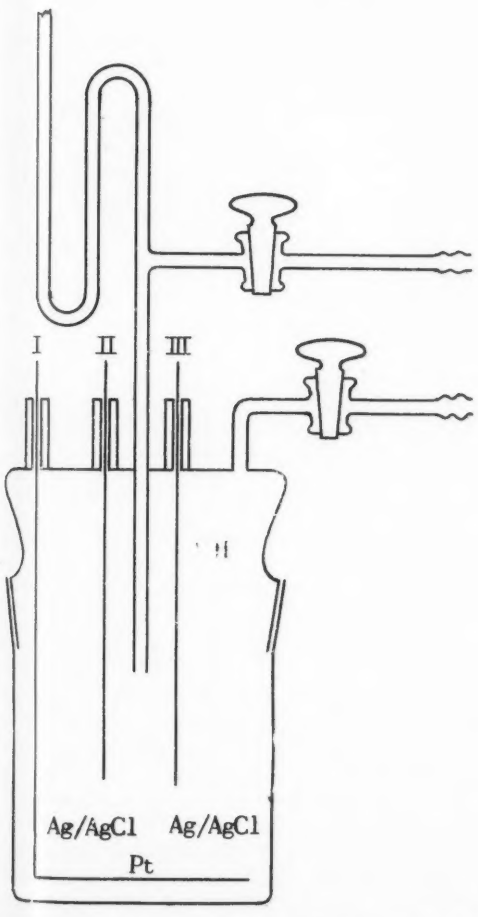


Figure 12—Apparatus for the study of the reaction between hydrogen and some oxidizing agents on platinum. I—platinum electrode. II, III—Ag/AgCl electrodes. M—water manometer.

TABLE C

E′ —E (overvoltage) Volt	Speed of Oxidation of Hydrogen (Equivs./sec.	Current Strength i (mA)
0.60	7.0×10^{-9}	0.70
0.36	1.2×10^{-9}	0.12
0.32	0.6×10^{-9}	0.06
0.00	0.0×10^{-9}	0.00

These values permit tracing the polarization curve of the reaction $H_2 \rightarrow 2H^+ + 2e$ drawn in Figure 13.

Summary

1. The affinity of an electrochemical reaction can be measured in magnitude and sign by the difference E′ —E between the "reaction potential" E′ of the surface on which this reaction occurs and the "thermodynamic equilibrium potential" E of this reaction. These two potentials are measured in relation to the same reference electrode.

The difference E′ —E can be defined as being the "overvoltage" of the electrochemical reaction under the experimental conditions realized.

The speed of the electrochemical reaction can be measured in magnitude and sign by the strength

i of the "reaction current" which corresponds to the reaction. This current i is regarded as positive when the reaction occurs in the direction of an oxidation and as negative when the reaction occurs in the direction of a reduction.

By applying to the case of the electrochemical reactions De Donder's relation $A \times v \geqq o$, according to which the product of the affinity A of a chemical reaction by the velocity v of this reaction is always positive or zero, the relation is obtained

$$(E' - E) \times i \geqq O,$$

which relates the direction of an electrochemical reaction to the sign of its overvoltage. An electrochemical reaction can occur only in the direction of an oxidation when its overvoltage is positive, that is, when the reaction potential E′ of the surface on which it takes place is higher than the equilibrium potential E of the reaction. An electrochemical reaction can occur only in the direction of a reduction when its overvoltage is negative, that is when the reaction potential E′ is lower than the equilibrium potential E.

The study of all of the electrochemical phenomena which can occur on the same metallic surface is facilitated by the knowledge of polarization curves which represent the influence of the reaction potential E′ on the velocities i_a, i_b, i_c ::: of the different possible electrochemical reactions.

2. These principles have been applied to the following systems:
   a) Behavior of electrically insulated iron.
      Behavior in absence of oxidizing agents (overvoltages and reaction potential).
      Influence of oxidizing substances on the potential and on the speed of corrosion.
   b) Behavior of iron not electrically insulated.
      Behavior of iron used as an electrolytic anode and cathode.
   c) Behavior of iron at high voltages. Electrochemical passivation and chemical passivation.
   d) Representations as a whole of the behavior of iron used as an electrode.
3. These principles also have been applied to a fundamental study which was published in 1938 by Wagner and Traud[10] on the reactions between hydrogen and some oxidizing agents on a platinum surface.

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Parts I and II

Aerobic Microbiological Corrosion of Water Pipes*

By ERIK OLSEN and WACLAW SZYBALSKI

PART I

AS IS WELL KNOWN, internal corrosion of water pipes is liable to occur in some areas. As often described in literature, such corrosions manifest themselves in the following way:

First, traces of rust are found to appear on the external surface of the pipes, and, subsequently, leakage occurs through an initially small hole in the pipe wall which, however, gradually increases in size.

On the internal side of the pipe wall, numerous crust- or tubercle-shaped dark-brown or ochre-coloured salient spots, of considerable size, can be detected. These prominences are porous and can easily be cut through with a knife. It then appears as if they consist of a dark-coloured to black core in the centre, which is surrounded by different, generally somewhat clearer, layers with a soft rust-coloured layer on the outermost side. The 'tubercle' chiefly consists of hydrated ferric hydroxides; pH 5—6. In the pipe wall, below the tubercle, a crater-shaped hollow is seen in the steel, deepest in the middle, where the pitting of the pipe initially occurs. Generally, concentric rings of less and less corroded parts of the crater appear toward its edge. In galvanized pipes the zink has generally disappeared below the tubercle.

Corrosion is most frequently found at many places in the same pipe and, generally, several or many neighbouring pipes show corrosion. Those parts inside a galvanized pipe which are not occupied by tubercles are, just as uncorroded pipes, covered with a smooth or granular, yellow or ochre-coloured layer, a so-called protective layer, which protects the metal against corrosion. According to Haase,[1] this layer consists chiefly of calcareous ferric hydroxides of variable composition, with an admixture of small quantities of Mg and Si.

A microscopic investigation showed that the tubercles, in addition to large quantities of amorphous ferric hydroxides, contained iron bacteria surrounded by sheaths; and, moreover, sometimes typical filaments of iron hydroxides from *Gallionella ferruginea*. The sheaths-forming bacteria were lying in coiled 'balls,' strongly incrusted by iron oxides and hydrox-

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Abstract

Tubercles found inside pipes in which water is flowing, in addition to large quantities of amorphous ferric hydroxides, contain iron bacteria surrounded by sheaths. Inoculated sterile tap water with an appropriate iron source, will provide a strong growth of iron bacteria. These bacteria, while not the direct cause of corrosion, primarily oxidize Fe^{+2} into Fe^{+3} whereby they gain the energy necessary for the assimilation of carbon dioxide. Iron bacteria sheaths assist in formation of a membrane relatively impervious to oxygen and in the process decrease the quantity of oxygen in the immediate vicinity, forming a micro-electrochemical cell. Experimental confirmation of the premise is claimed through the use of differential aeration cells created by using germ filtered water with and without inoculation with iron bacteria. Iron bacteria play a decisive role in initial formation of the differential cells but a minor one in establishment of anaerobic conditions under the tubercle during the main period of the corrosion. After tubercle formation corrosion proceeds practically independently of the metabolic activity of iron bacteria. Inhibition of further corrosion is attempted by changing the equilibrium of the water to form a layer of chalky rust on the tubercle.

* Reprinted from *Acta Chemica Scandinavica*, Vol 3, 1094-1116 (1949).

ides. When this was dissolved with hydrochloric acid, the bacterium filaments or, more correctly, the empty sheaths, became clearing visible.

When inoculated in sterile tap water with a nail as iron source, a rather strong growth of the thread-forming bacteria can be obtained, which seems to be a *Leptothrix sp.* Thus, there may be a possibility that iron bacteria in one way or another play a part in the corrosion phenomena described above. These bacteria, which cannot corrode metallic iron, are, however, certainly not the direct cause of the corrosion; but, as was first shown by Winogradsky,[2] primarily oxidize Fe^{+2} into Fe^{+3} (by means of oxygen dissolved in water), whereby they gain the energy necessary for the assimilation of carbon dioxide and the building up of the organic substances of the cells. This is a process analogous to that in which the green plants use the energy of the sunlight. Thus, iron bacteria are autotrophic organisms; but as they are still scantly explored, it is unknown whether others than *Gallionella* are obligate autotrophic.

In summary, the formation of energy can be expressed by the following equation:

$$2\,Fe^{+2} + (x+2)\,H_2O + 1/2\,O_2 \rightarrow Fe_2O_3 \cdot xH_2O + 4H^+ + Q\ \text{cal}$$

Ferrous ions are taken up in the bacterial cells where they are oxidized to ferric ions which are discharged and gradually hydrolyzed. Subsequently, they coagulate in the surrounding water and are precipitated as hydrated ferric hydroxide.

According to Beger,[3] sheaths, without bacteria or with dead bacteria, are able to precipitate ferric hydroxide for a long time, only more slowly than the living bacteria.

In the literature, indications are found of the assumption that iron bacteria may play a part in corrosion. Most frequently, however, the injurious effect of iron bacteria in water pipes became obvious by the fact that their abundant growth made the water muddy (so-called 'red-water') and caused blockage of the narrow pipes (*e. g.* Schorler[4]). Brown[5] described such formations and showed a cross section of an old tubercle. It appears as if its central part consists of a dark core, which is largely iron sulphide, which is surrounded by some layers of a yellowish-red "iron-meal," containing numerous *Gallionella*-filaments incrusted with ferric hydroxide, chalk, and manganese. The external layer is a mantle or iron hydroxide and chalk with a coating of living *Gallionella.*

Schorler[4] also found that the tubercles initially consist of a loose *Gallionella*-felt, which later disappears and is recrystallized in the form of hexagonal hematite-(Eisenglanz)-like crystals. These crystals grow together into shapeless aggregates, in which no iron bacteria can be distinguished. Ellis[6] mentions that iron bacteria, in water pipes, cause 'slimy streamers, tubercular incrustations,' the formation of which is furthered by carbon dioxide, and 'iron incrustation on non-ferrugineous surfaces.' The other physiological and bacteriological theories of this author, which have been strongly critisized by Winogradsky,[2] will not be further discussed here.

Herman[7] observed very large incrustations of iron bacteria *(Gallionella)* in asphalt-coated pipes. In uncoated pipes or in pipes where the asphalt was damaged, deep corrosions (pitting) with superimposed tubercles were found. Inside the tubercle recrystallization to hematite (Eisenglanz) was seen to occur. Thresh, Beale and Suckling[8] state that 'they (iron bacteria) may play some part, probably a subordinate one, in the formation of tubercular incrustations in iron mains. This leads to interference with the flow of the water, and destruction of the pipes.'

Minder[9] reports that by immersing polished iron strips into wells, the growth of iron bacteria is initiated and that corrosion takes place under the crust. Similar phenomena were found to occur in the filter kettle of a closed iron-removing plant. On the wall above the sand were found lens-shaped, rust-coloured deposits, several cm in diameter and up to 1 cm thick. Under these deposits hollows in the iron wall appeared. After drying, the 'lenses' were light almost like a dry sponge and consisted of a felt of iron bacteria.

Beger[3] assumes that *Gallionella ferruginea* is alone responsible for incrustation in pipes and is contributory to corrosion.

Other authors, however, have found that *Leptothrix ochracea* and *Crenothrix polyspora* also very frequently grow in water pipes.

Haase,[1] who thoroughly dealt with these problems, stated that water causing corrosion (pitting) always contained a great deal of organic substances and iron bacteria.

Von Wolzogen Kuhr[10] has shown in a very convincing way, that external corrosion of iron pipes buried in the soil may be due to sulfate-reducing bacteria. These are anaerobic and use oxygen from sulphates for oxidation of organic substances and, to a minor degree, also for oxidation of hydrogen for production of energy—at the same time forming hydrogen sulphide.

Starkey,[11] furthermore, directs attention to the fact, that the presence of oxygen concentration cells in the soil should be considered. Thus, for instance, a pipe buried in a moist anaerobic area will prove to be anodic in relation to another piece of the same pipe in a well-aerated moist area, where the hydrogen produced is oxidized to water by the oxygen of the air. Iron is dissolved on the anode and is transformed into ferrous hydroxide, and, if sulphate reducing bacteria are present, also into iron sulphide.

We are, of course, here concerned with quite other conditions than those prevailing in water pipes with a more or less continuous current of airsaturated water, and the above mentioned papers on sulphate reducing bacteria have been mentioned only in order to show that corrosion may be due to biological causes.

Bunker[12] (and, also Butlin, Adams and Thomas[13]) assumes that the sulphate-reducing bacteria may be active under the anaerobic conditions under the tubercles, and he has isolated *Vibrio desulfuricans* from such places. It can hardly be doubted that the conditions for growth are favourable here, since there are organic substances from water and destroyed bac-

terial cells,* a small supply of sulphate-containing water, and rather anaerobic conditions.

A review of the literature thus has shown, that frequently tubercle formations, connected with pitting, occur similar to those cases discussed in the present paper. Iron bacteria were always found—most frequently *Gallionella ferruginea*, but also *Leptothrix ochracea* and others—as constituents of these tubercle formations. All authors agree about the necessity of a cautious statement of the part played by iron bacteria in connection with these phenomena (Knudsen,[15] Reddick and Linderman,[20] Thomas,[21] Brown,[22] O'Connel,[23] Pillai, Rajagopalan and Subrahmanyan[24]).

The manuals available, dealing with metal corrosion, also pass lightly over this question; thus Kröhnke, Maas and Beck[16] (p. 88) write, that the growth of bacteria is found on the internal walls of water pipes, and at the bottom and on the sides of water reservoirs, partly as 'schlemige Streifen,' and partly as 'Verkrustungen' or tubercles. By the activity of the iron bacteria, a danger of obstruction and corrosion arises. In the handbook on corrosion by Bauer, Kröhnke and Masing,[17] no notice is taken of microorganisms in connection with corrosion; only the investigations of von Wolzogen Kühr on sulphate-reducing bacteria are mentioned.

Evans[18] states that iron bacteria, no doubt, often are connected with a rapid perforation of the material; their activity ceases at pH 8.2—8.6.

Hadley[19] writes that the role of iron bacteria in corrosion is still obscure. Their most important contribution to corrosion probably results from the creation of a barrier capable of maintaining oxygen concentration gradients between metal and solution. 'Additional data are admittedly required to clarify the relationship which exists between the iron bacteria, the sulphate-reducing bacteria, and tuberculation.'

The authors believe that iron bacteria are of considerable, primary significance in the development of corrosion and the formation of tubercles. We now shall make an attempt to explain how this interpretation is in agreement with the facts.

Mechanism of Corrosion

It is generally assumed, that corrosion in water pipes (only internal corrosion of iron water pipes conducting well-aerated tap-water of normal hardness is discussed here) depends essentially on the existence of short circuited local cells, an assumption whose general validity can hardly be doubted. Differences of opinion only arise in the discussion of details of the mechanism. For a survey of these problems reference is made to the book by Evans,[18] from which theories, which are in best agreement with experimental data have been taken. (Only the theory of bacteria playing an essential part seems to be new.)

It is of some importance to know the relative size and distribution of anodic and cathodic areas (anodic: places where the electric current passes from the metal to the liquid, cathodic: places where the current goes in the opposite direction). If cathodic and anodic areas are quite evenly distributed over the whole internal surface of the iron pipe, corrosion everywhere on the surface is possible with an even diminution of the thickness of the wall. This type of corrosion is due to heterogenic structure of the iron surface with evenly distributed non-iron impurities, and is not very dangerous on account of the very low rate of destruction. The mechanism of this type of corrosion is shown in Figure 1. In the present case, however, it is known by experience, that supply pipes tend to rust locally ('pitting'). This means, of course, that the anodic areas, the places where metallic iron is dissolved according to the equation:

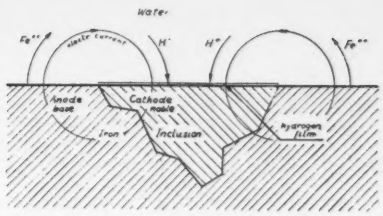


Figure 1—Scheme of the corrosion in non-aerated water due to the activity of local electrochemical cell.

$$Fe \rightarrow Fe^{+2} + 2e \qquad (1)$$

are relatively small.

It can therefore be assumed either that some factors making the metal less noble (more negative) occur in isolated spots, and that the cathodic (nobler, less negative), areas are more extended (which, of course, means that the current density is great at the anodic spots and small on the cathodic areas); or that impurities making the metal nobler (more positive) occur over extended areas and that the more negative places occur in isolated spots.

The causes of the differences in electrochemical behaviour may be of various kinds; *e. g.* the well known passivating action of oxidizing agents, *i. e.* oxygen itself may very well play an important role. One might, for instance, imagine that almost the whole inner surface of the tube is passivated (made nobler) by oxygen, but that some spots, for one reason or another, remain active.

However, it is not necessary, at present, to dwell on these different possibilities and theoretical aspects. What is needed is: 1) a mechanism which will initiate corrosion at certain spots and 2) a mechanism to make the conditions stationary and favourable to corrosion at the same spot for an extended period of time.

1. The start of the corrosion requires, of course, not only the occurrence of reaction (1) in one place, but also a reaction whereby electrons are used up. In view of the conductivity of the metal this reaction may take place anywhere on the surface and over extended areas. One possibility is the reduction of water:

$$2e + 2H_2O \rightarrow H_2 + 2OH^- \qquad (2a)$$

* According to Butlin and Adams[14] sulphate-reducing bacteria can live under strictly autotrophic conditions.

another the reduction of oxygen

$$2e + 1/2\ O_2 + H_2O \rightarrow 2OH^- \qquad (2b)$$

According to Evans both may occur, but it is obvious that (2b) is by far the most probable.

It is highly probable that they take place through intermediary stages, some of which are identical to both reactions. As such steps one might imagine:

$$H_2O \rightleftharpoons H^+ + OH^-$$
$$e + H^+ \rightarrow H$$

and it must be assumed that the hydrogen atoms are adsorbed on the cathodic areas. From these areas they are removed either by association (formation of H_2) or by reaction with oxygen (formation of H_2O). This latter reaction probably also proceeds through intermediates (HO_2, H_2O_2) but, for the present purpose, it is not necessary to enter into details on this point.

Another point, however, seems rather important. The water contains not only oxygen, but also dissolved carbon dioxide, which must react with the hydroxyl ions according to the well-known scheme. Consequently, we get instead of (2b)

$$2e + \tfrac{1}{2}\ O_2 + H_2O + 2CO_2 \rightarrow 2HCO_3^- \qquad (2c)$$

Obviously, the corrosion thus displaces the equilibrium

$$CO_2 + H_2O \rightleftharpoons H^+ + HCO_3^-$$

towards the right. This has the consequence that, if the water originally was saturated or nearly saturated with calcium carbonate, which very often is the case, the corrosion process will cause a supersaturation resulting in a tendency of the water to form scale.

Conclusions: At the start, anodic spots in cooperawith more extended cathodic areas will cause the occurrence of closed electric currents coupled with chemical reactions:

$$\text{anodic: } Fe \rightarrow Fe^{+2} + 2e \qquad (1)$$

$$\text{cathodic: } 2e + \tfrac{1}{2}\ O_2 + H_2O + 2CO_2 \rightarrow 2HCO_3 \qquad (2c)$$

2. For the reaction to proceed it is necessary to protect the anodic (active) spot against the influence of passivating agents, *e. g.* oxygen. Now, especially if water in the pipe is stationary, this can easily be achieved. Quite apart from the electrochemical process described above the ferrous ions are easily oxidized to ferric ions or, in not too acid solution, to hydrated ferric oxide, the stoichiometrical equation being:

$$2Fe^{+2} + \tfrac{1}{2}\ O_2 + (x+2)\ H_2O \rightarrow Fe_2O_3 \cdot xH_2O + 4H^+$$

As the ferrous ions and the oxygen come from either side, a film of colloidal hydrated ferric oxide may be formed around the anodic spot. Inside this film the oxygen concentration will remain low on account of the continual flow of ferrous ions released from the active spot, which consumes the oxygen diffusing in from the outside. At the same time, the hydrogen ion concentration remains rather high and, in case such a film can be formed and remain undisturbed, the conditions will be highly favourable for the process to continue. Concerning the cathodic process whose occurrence, of course, is just as necessary as the anodic one, there seems to be no great probability of its inhibition. The surface of the cathodic areas must be expected to be rather easily accessible for dissolved oxygen which, thus, without difficulty can exert its depolarizing influence (removal of hydrogen atoms).

Remembering the low density of the cathodic current, one would expect that only a hard, tight scale with excessively low electric conductivity and high resistance again diffusion might have some effect.

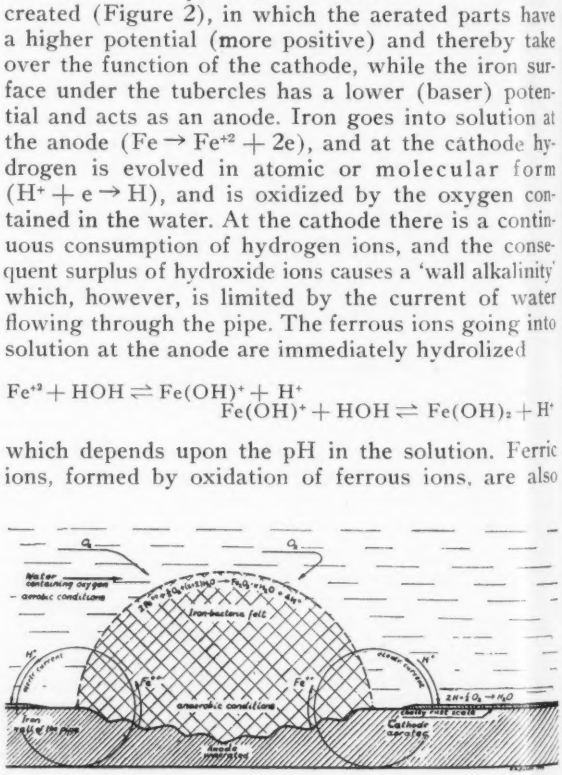
It thus seems possible that a purely inorganic mechanism may be operative, but, if the conditions prevailing around the anodic (active) spots are considered, it soon becomes clear that they are ideal for the growth of certain bacteria and that, on the other hand, a colony of these bacteria will be ideal for maintaining the conditions of corrosion at that spot.

The Theory of the Aerobic Bacteriological Corrosion

The types of corrosion described in the introduction to this paper are, no doubt, caused by electrochemical processes. The iron surface is divided into two systems, under and outside the tubercles. The water of the supply pipes in question contained about 8 mg/liter of oxygen. The non-tubercle areas are violently washed by this water and consequently aerated. Under the tubercles, however, there is a very slow percolation of the water and consequently weak aeration. Thereby, a short-circuited electric cell is created (Figure 2), in which the aerated parts have a higher potential (more positive) and thereby take over the function of the cathode, while the iron surface under the tubercles has a lower (baser) potential and acts as an anode. Iron goes into solution at the anode ($Fe \rightarrow Fe^{+2} + 2e$), and at the cathode hydrogen is evolved in atomic or molecular form ($H^+ + e \rightarrow H$), and is oxidized by the oxygen contained in the water. At the cathode there is a continuous consumption of hydrogen ions, and the consequent surplus of hydroxide ions causes a 'wall alkalinity' which, however, is limited by the current of water flowing through the pipe. The ferrous ions going into solution at the anode are immediately hydrolized

$$Fe^{+2} + HOH \rightleftharpoons Fe(OH)^+ + H^+$$
$$Fe(OH)^+ + HOH \rightleftharpoons Fe(OH)_2 + H^+$$

which depends upon the pH in the solution. Ferric ions, formed by oxidation of ferrous ions, are also



Figures 2—Scheme of the corrosion in well-aerated, running water after the formation of a "tubercle" (from an iron bacteria "felt") on the internal surface of a water pipe.

hydrolyzed and to a much higher degree than ferrous ions (the hydrating of the ions is not considered here). By the hydrolysis, hydroxyl ions are consumed and the surplus of hydrogen ions causes an acid reaction, which, as mentioned before, has been ascertained in the tubercles. This acid reaction in itself accelerates corrosion, as: (i) it causes greater electrical conductivity and (ii) renders difficult the formation of carbonate-containing, protective scale of "chalky rust" on the surface of the tubercle so that no increase of the electrical resistance takes place. The resistance of the cathodically formed protective scale has no very great effect because of the large surface of the cathode and the consequently low density of current in comparison with the small corroding anodic surface under the tubercles.

The whole of this phenomenon, however, depends upon the formation of a membrane which renders difficult the percolation of water, and the diffusion of oxygen but without much resistance to the transference of ions. This membrane may also appear in connection with purely inorganic colloidal precipitations of hydrated ferric oxides where the admission of oxygen is rendered difficult by the fact that the diffusing oxygen is consumed by oxidation of ferrous ions to ferric ions. The colloidal hydrated ferric oxide, however, is of a granular structure and is mechanically of small resistance. Consequently, it is not always probable that in pipes with running water such membranes could be formed in a purely inorganic way without any other factors. In this connection the iron bacteria should first be considered, as filaments of iron bacteria are always found in tubercles, which is known partly from the literature partly from the authors' investigations of tubercle-formation. It should be imagined that the iron bacteria settle on the iron surface, chiefly, perhaps, on rough spots (tubercle-formations thus are often found on the welded seam). The bacteria then start multiplying and, as mentioned before, gain energy by oxidation of ferrous into ferric ions. Thereby the concentration of oxygen in the immediate vicinity decreases and a local micro-electrochemical cell is formed. On the areas deficient in oxygen, *i. e.* where the bacteria colonies are to be found, ferrous ions go into solution. This favours the growth of the bacteria.

The iron bacteria will find the best conditions of life in neutral or slightly acid water containing ferrous ions, oxygen, some free carbon dioxide, and ammonium salts or nitrates. Pipe corrosion shows all the above conditions—on the anodic surface iron is electrochemically dissolved as ferrous ions, and by their hydrolysis the slight acid reaction appears. Simultaneously free carbon dioxide is formed with carbonates according to the reaction:

$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$$

Thereby all conditions for the development of bacteria (even good conditions of temperature and absence of light) are present, and the bacteria contribute to the corrosion in three essential ways:

1. Primary formation of micro-differential-aeration cells due to a change in concentration of oxygen in the infected place. This cell may develop further either in a bacteriological way or, perhaps, in a purely inorganic chemical way.
2. Mechanical strengthening of tubercle owing to the 'felt structure' of iron bacteria filaments.
3. Catalytic oxidation of ferrous ions and, consequently, rapid precipitation of hydrated ferric oxide, which further strengthens the anaerobic conditions on the anodic side and, hence, increases the difference of potential between the iron surface under and outside the tubercle, whereby corrosion is increased.

It follows from the theory stated here that all microorganisms which are able to grow under these conditions, to consume oxygen, and form compact colonies, can develop or increase corrosion. As already stated iron-bacteria particularly will find favourable conditions of life in new water pipes and consequently become predominant.

An electrochemical and bacteriological investigation of the consequences of the theory is reported in a following paper.

Summary

In the present paper a description is given of a type of corrosion in water pipes. The corrosion is accompanied by the formation of 'tubercles' consisting mainly of hydrated iron oxides and iron bacteria felt which lie over the pittings. The electrochemical nature of this corrosion is discussed and a theory advanced according to which microorganisms, especially iron bacteria, accelerate these processes.

It is proposed that

1. through their growth on limited regions of the iron surface the iron bacteria primarily form 'differential aeration cells.' These give rise to a difference of potential and consequently to a corrosion current between the site of the bacterial colony and the surrounding surface of the iron.
2. the felt-like structure of the sheaths of the iron-bacteria causes a mechanical strengthening of the tubercle, which becomes resistant to the flow of water in the main.
3. with increasing thickness of the tubercle the conditions inside the tubercle will be more anaerobic. This increases the difference of potential between the iron surface under and outside the tubercle, and the corrosion is thereby increased, with or without the collaboration of the bacteria.

The authors wish to express their gratitude to Professor J. A. Christiansen, head of the Chemical Laboratory A, and Professor J. L. Mansa, head of the Mechanical Engineering Laboratory of the Technical University of Denmark for their information and helpful discussions during the performance of the present work. Special thanks are due to Professor J. A. Christiansen for his interest and efficient help in our work with the section on mechanism of corrosion. We also wish to thank Dr. K. R. Butlin and Mr. N. Hofman-Bang, C. E., for their kind assistance in translating this paper.

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PART II

IN A PREVIOUS PAPER,[1] we have dealt with corrosion and proposed the hypothesis that iron bacteria play a prominent, primary part in this phenomenon of electrochemical nature. In our opinion, their mode of action should be as follows:

1. Primarily, the formation of 'differential aeration cells' by the growth of iron bacteria on limited regions of the iron surface.
2. The felt-like structure of the sheaths of iron bacteria causes a mechanical strengthening of the 'tubercle,' which becomes resistant to the flow of water in the main.
3. Increasing anaerobiosis below the tubercles formed by the iron bacteria which are oxygen consuming. Hereby, the anode potential decreases and the potential difference between the anode (under the tubercle) and the cathode (outside the tubercle) and, consequently, the corrosion flow increase.

In the present investigation an attempt has been made to obtain experimental corroboration of our assumptions.

As a first step towards the verification of the assumption that the corrosion is of bacterial origin, a bacteriological investigation of the tubercle has been carried out. As mentioned in the previous paper, it was observed that those parts of tubercle shells, found in the closest proximity to the iron surface, consisted of amorphous, recrystallized hematite (Eisenglanz) and, towards the surface, of a felt of mostly empty, largely iron-incrusted sheaths of iron bacteria. This is most beautifully seen on younger tubercles (2—3 months old). In Figure 1 such a felt is depicted in ca. 20 fold magnification. The surface of the tubercle is removed. It consists of an ochre-yellow, porous, amorphous, very thin layer of strongly

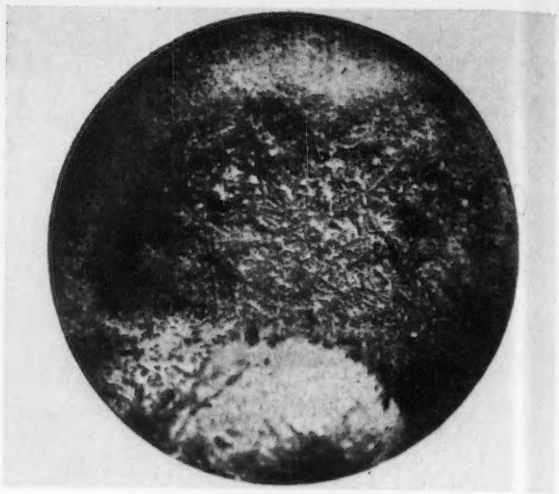

Figure 1—Internal structure of a 3 months old tubercle. The single threads covered with a very thick knotted sheath are easily seen. Magnification ca. 20 x.

Figure 2—Scheme of the formation of the sheath. a—uncovered, young threads. b, c—the threads covered with single grains of hydrated hematite. d—completely developed sheath.

hydrated ferric oxide, which is easily soluble in dilute hydrochloric acid. The iron compound in the recrystallized layer and in the sheaths of the iron bacteria is sparingly soluble in dilute hydrochloric acid.

The bacterium felt shows little electric resistance, but is an effective membrane inhibiting both percolation of water and oxygen diffusion.

In our experimental pipes, iron bacteria grew especially well on bakelite packings, while a continuous flow of tap water was led through the pipes. Here, a velvet-like, rather firmly fixed layer of iron bacteria developed.

Long threads, approx. 1 μ thick and 100—500 μ long, were formed. Most of these were entire, however, many of them were divided into separated cells, 1×10 μ large. The older threads were surrounded by a yellow-brown sheath of hydrated ferric oxide, while the quite new ones lacked these sheaths. With increasing age the sheaths become darker brown and thicker. Incrustation seems to occur in such a way that single grains of hydrated ferric oxide appear on the sheath and, in the course of time, a larger and larger number of grains develops until, finally, the whole surface is covered by a brown, knotted layer (Figure 2).

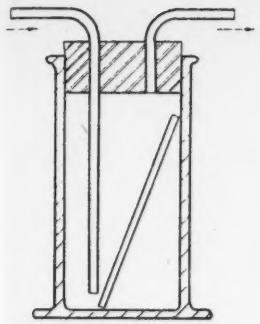

Figure 3—Glass cylinder with a piece of iron sheet for experiments with sterile and unsterile water. → indicate the flow of water.

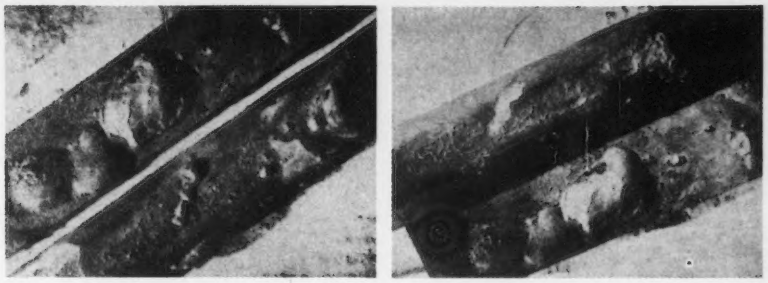

Figure 4 (left) and 5 (right)—Iron sheet pieces with well developed tubercles. After removal of the tubercle, the corrosion cavities become visible (on the upper iron piece of Figure 5).

Generally, the threads appear to be unbranched, but some are actually ramified. Morphologically, they seem to belong to the *Crenothrix* group, but some types forming ramifications recalled definitely the *Clonothrix* or *Leptothrix* types.

At the present time, however, the classification of iron bacteria is rather doubtful, and it appears probable that the multifarious types should in reality be condensed into a few, since the morphology, the most important grouping basis, may vary considerably according to the exterior conditions (*cf.*, for example, Beger,[2] Bergey,[3] Pringsheim[4]).

It was our aim to elucidate whether iron bacteria are the primary cause of tubercle formation and, correspondingly, of corrosion. We have, therefore, investigated whether germ filtration of tap water suppresses these phenomena, and whether inoculation of sterile main water with iron bacteria causes tubercle formation. The experiments were performed in the following way.

Main water was directly filtered through a Seitz filter into a level flask. From here, it was led into two parallel series of sterile glass cylinders (200 ml), each containing a square piece of iron sheets, $20 \times 100 \times 0.5$ mm (Figure 3).

Into the first cylinder of one of the (inoculated) series was mounted a piece of folded filter paper containing a culture of iron bacteria—this caused a very vigorous inoculation. Unfortunately, we have not yet succeeded in producing a completely pure culture of bacteria, but there is no reason to assume that this should affect the results presented here.

After a lapse of 4—6 days, the metal sheet plates in the uninoculated series were covered with a thin, firm, protective layer ('chalky rust').

In the inoculated series, however, small, velvet-like colonies on the iron surface appeared after a few days. They grew rather rapidly into common tubercles with light-yellow, rather smooth and porous surfaces and, after 2—3 months, they were up to approximately 2 cm in diameter and 5 mm high.

In other experiments, non-sterile tap water was led through glass cylinders with iron sheet plates without special previous inoculation. Also in these cases, the growth of the bacteria appeared, even after a presumably very slight inoculation. In the last mentioned experiments, however, single tubercles were observed which were spread over the surface of the iron sheet, while after strong inoculation almost the whole surface was overgrown. Figure 4 shows the appearance of the tubercles and, in Figure 5, corrosion is seen after the tubercles were removed from the iron sheet pieces. Figure 1 is also taken from this experiment.

Hence, it was possible to show that sterile water does not cause tubercle formation and, moreover, that the iron bacteria are the cause of tubercle formation and, correspondingly, of corrosion.

In order to further prove the significance of iron bacteria in iron corrosion, a series of experiments were performed in which it was attempted to produce the effect of the tubercles by means of artificially constructed 'differential aeration cells.'

Figure 6a shows schematically the conditions prevailing in a water pipe. Under the membrane ('the tubercle') built up by the iron bacteria we have stagnant, practically oxygen-free water, and the underlying part of the iron surface acts as the anode. The iron surface outside the tubercle is continuously

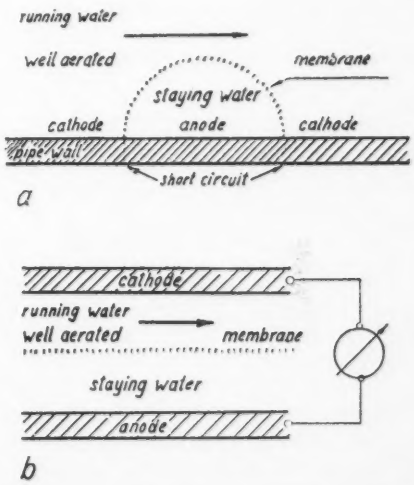

Figure 6—Schematic comparison of the conditions during pitting with tubercle formation and by artificial differential aeration cell.

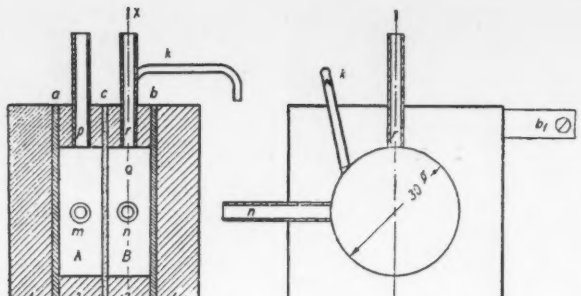

Figure 7—Differential aeration cell. 1,4—external bakelite plates. 2,3—internal bakelite plates; the holes drilled form the real cell compartment A-B. a,b—iron plate electrodes. b—terminals for the electric connection of the iron electrode with the measuring apparatus. c—membrane made of filter paper. m,n—water inlet pipes. p,r—water outlet pipes. k—agar salt bridge for the potentiometric measurements.

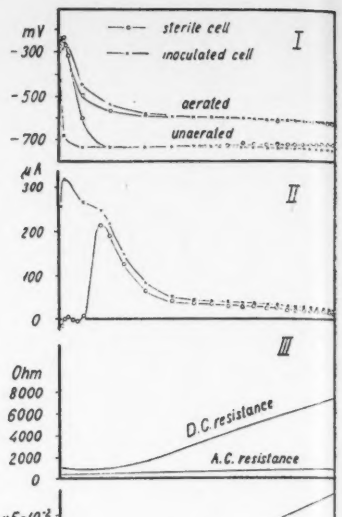

Figure 8—I. Time-potential curve of the aerated electrode (cathode) and the unaerated electrode (anode) for sterile and inoculated differential aeration cell. II. Time corrosion current curve. III. Time d.c. resistance curve. Time a.c. resistance curve. IV. Time capacity curve. The curves III and IV are practically identical for inoculated and uninoculated cells.

in contact with water saturated with air and, therefore, forms the cathode relative to the covered part. The two terminals are short-circuited through the pipe wall.

In order to imitate these conditions, two iron plate terminals were placed parallel to each other and separated by a membrane of hardened filter paper. In this way, the cell formed two compartments, one of which containing stagnant water, while continuous flow of water passed the other compartment of the cell. The two iron plates, short-circuited through a microamperemeter, thus formed anode and cathode, respectively. The principle of this arrangement is seeen in Figure 6b.

Figure 7 shows the construction of the cell. It consists of four bakelike plates (denoted by 1, 2, 3, 4), $50 \times 50 \times 10$ mm. A hole, 30 mm in diameter, was drilled into the two central plates (2, 3), whereby an internal cylindrical cavity (A•B) was formed.

At the ends of this cavity, two iron plates (a, b) were placed, their position being fixed by the external bakelite plates. The filter paper membrane (c) was placed between the two internal bakelite plates, thus dividing the cell into two compartments (A and B), each 10 mm deep and 30 mm in diameter. The arrangement was held together by iron clamps (not shown in Figure 7).

Through the bores of the internal bakelite plates, water could pass into and out of the two compartments of the cell through cemented glass tubes (m, n, p, r).

During the experiment proper, water was led through one compartment (A) only, while the other one (B) contained stagnant water. During the corrosion process, the oxygen will rapidly be consumed and the iron plate, therefore, become anodic relative to the other plate which is in continual contact with oxygen containing water. Oxygen diffuses only slowly through the hardened paper and, in the compartment with stagnant water, we shall therefore rather soon find (after some hours) that highly anaerobic conditions prevail near the iron surface, becoming more and more aerobic in the direction of the membrane.

The iron plates were short-circuited except for the time when the measurements were performed. These included corrosion current as a function of time, potential between the iron plates, their individual potentials measured by means of a calomel electrode (saturated KCl), the internal resistance of the cell to d.c. and a.c., and the electric capacity of the cell.

The water flow was 100 ml/min. Each experiment lasted for 15—30 days.

In the first experiments, ordinary main water flowed through the cell. When the cell was opened after the lapse of 3 weeks, vigorous growth of iron bacteria was found to occur on the non-aerated part of the filter paper membrane. The bacteria formed a 1—2 mm thick felt. The non-aerated electrode (anode) was quite bright and homogenously affected. The weight loss of this electrode approximately agreed with the loss calculated from the measurements of the corrosion current, the weight loss being about 10 percent higher than the Coulomb equivalent of the current. The cathode was covered with a compact, thin, yellow layer of 'chalky rust' which stuck firmly. The cathode seemed to be especially well protected under this layer.

The described development of iron bacteria was observed in all cases where untreated main water was led through the cell. This apparatus can, therefore, also be applied to the demonstration of iron bacteria in water.

For the sake of comparison, a series of experiments was carried out under sterile conditions, the water being germ-filtered through Seitz filters and led through two parallel cells of the type shown in Figure 7. One of the cells was strongly inoculated by introducing the iron bacteria grown in the above mentioned experiments into the anodic part of the cell, the other one remained sterile. The results of these measurements are shown in the diagrams

(average of 5 series), and it appears that the bacteria have a rather small, but pronounced effect on the decrease in potential of the non-aerated electrode, which causes a greater potential difference between the electrodes and an increase in the corrosion current (Figure 8, I).

It could, however, be observed that strong inoculation with iron bacteria very rapidly brought forth a decrease in the electric potential of the non-aerated electrode to the ensuing, rather constant value observed later.

The potential of the aerated electrode decreased much slower owing to the high EMF of the cell at the start of the experiment and, thus, of the vigorous corrosion current (Figure 8, II).

In the uninoculated cell, however, a rather simultaneous decrease in electric potentials of both electrodes could be observed. The potential difference thus fluctuates around zero and, therefore, in the first hours of the experiment, the corrosion flow shows low positive and negative values* (Figure 8, II).

This difference in the initial course of corrosion indicates that iron bacteria may be the primary cause of corrosion in new pipes. In regions where the bacteria are deposited, the potential of the iron decreases rapidly, whereby primary micro-differential aeration cells are formed. Corrosion and formation of 'tubercles' by precipitation of hydrated ferric oxide start momentarily and, simultaneous, also the bacteria colonies grow.

Experiments with sterile water, moreover, showed that, in the course of a week, the potential of the anode was —720—740 mV, measured against a calomel electrode (saturated KCl). This potential deviates, practically spoken, only very little from the potential of the iron in completely O_2-free medium under otherwise similar conditions.**

From these results it becomes clear that the iron bacteria cannot futher decrease the potential of the anode. After 'tubercles' have been formed, the iron bacteria practically do not play any part in the progressing corrosion. In our experiments, the iron bacteria caused an average increase in corrosion by ca. 10 percent (Figure 8, I and II).

Thus, there is no possibility of inhibiting corrosion by killing the iron bacteria. However, such a measure—for example, frequent addition of chlorine to the main water—will presumably suppress the formation of new corrosion fields.[8,9]

One way in which inhibition of corrosion might be obtained is to cover the tubercles with a thick protective layer. Hereby, the current density on the anode is largely decreased and the corrosion effectively inhibited.

The normal equilibrium water (with respect to the system $CaCo_3$—CO_2—H_2O, Bauer, Kröhnke, Masing[8] and others), forming protective 'chalky rust' layers in iron pipes, will not form such layers on the tubercle surface because of the hydrolysis of ferric and ferrous ions which gives an acid reaction. The equilibrium (pH) of the water is changed and the water dissolves chalk rather than forming protective layers. Only after alkalizing the water (for example, by addition of lime water or filtration through freshly burnt magnofilters) do the conditions on the surface of the tubercles favour the formation of tight layers of 'chalky rust.'

Preliminary experiments indicated that newly filled magnofilters completely inhibit the formation and growth of 'young tubercles' (Mansa[7]).

We found that fresh magnofilters increase the pH by 0.5—0.8, while a filter with old filling (ca. 6—12 months old) only caused an increase in pH of 0.1. This filter proved to be ineffective in preventing corrosion.

The effect of freshly burnt magnofilters seems to be based not only on the adjustment of the equilibrium state of the water, but also on the alkalization. This involves a supersaturation with chalk which, in the course of time, causes (1) precipitation of a protective layer on the 'tubercle' in a zone where the degree of acidity is suited for the readjustment of the equilibrium of the water, and (2) precipitation of a porous layer of $CaCO_3$ on the wall of the pipe outside the 'tubercles' which may choke up the pipe. Therefore, the alkalization of the water must be performed very cautiously, in the right places, and over the right period of time.

It can easily be shown that water which passed through a fresh magnofilter and is supersaturated with chalk is above the equilibrium curve of the Tillman and Heublein[6] diagram (p. 224). If ca 50 cm long glass tubes are inserted in both sides of the magnofilter, a thick chalky precipitate is observed on the walls of the tube inserted behind the filter, while the tube leading to the filter is unchanged.

After precipitation of the excess chalk, protective layers on or inside the tubercles can no longer be formed. The pretreatment of the water should, therefore, be performed in the proximity of those parts of the pipe which must be saved, for example by instalment of a magnofilter in the attacked houses for a short period of time (some months).

Finally, it should be mentioned that, in parallel experiments with inoculated and uninoculated cells, the internal resistance of the cell to a.c. and d.c., and the electrical capacity, did not show any deviation (Figure 8 III and IV). However, the results are typical. The initial d.c. resistance* of ca. 800 ohms increased after the lapse of 24 hours and after 8 days it was 7—8 times as high.

At the same time the a.c. resistance** increased only by ca. 50 percent. The capacity of the cell increased in the beginning proportional to the d.c. resistance.

These observations may be interpreted as follows. Let us consider the scheme of Figure 9. In the beginning, we have only the resistance (R_1) of the water layer between the electrodes. The two iron electrodes, separated by the water layer, form a condenser (C_1). (E) is the electromotive force of the cell. These values change only insignificantly in the course of the experiment.

By the formation of the chalky rust layer more or less covering the cathode surface, two new compo-

* This must be considered the explanation of the undefined direction of current in the beginning of the experiment with "differential aeration cells" as discussed by Evans[5] who, however, does not explain the phenomenon.

** After some days the potential of the iron in O_2-free main water was rather constant—775 mV against a calomel electrode (—553 mV against normal H_2-electrode). The concentration of ferro-ions was 0.85 millimol/1. These values are in good agreement with the normal potential of the iron,—441 mV against a normal H_2-electrode.

* The d.c. resistance was calculated from the changes in current caused by an increase in the external resistance of the circuit by 500 ohms. The inner resistance of the micro-amperemeter was 20 ohms.

** The a.c. resistance was measured by means of a Wheatstone bridge. A tube generator with a frequency of 1000 cycles served as a current source. The capacity of the cell was balanced by a variable condenser inserted parallel to the variable decade resistance of the Wheatstone bridge.

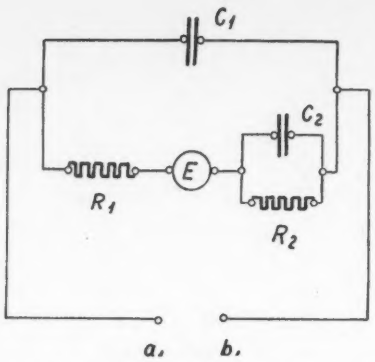

Figure 9—Electrical scheme for the differential aeration cell (explanation in the text). a, b,—the terminals of the iron electrodes.

nents (R_2 and C_2) appear which cause the vigorous increase in total resistance and capacity of the cell.

If the chalky rust covered cathode is replaced by a new iron sheet, the initial C_1 and R_1 values are re-established.

It might be possible by means of this 'differential aeration cell' to measure quantitatively the capacity of the water of forming protective layers. In this case, all dimensions and all experimental conditions must be standardized.

Summary

An attempt was made to prove experimentally our previous hypothesis regarding the activity of iron bacteria during corrosion of water pipes. This hypothesis comprised three arguments.

The first and second arguments, the primary formation of the 'differential aeration cell' by iron bacteria and the mechanical reinforcement of the 'tubercle' could be completely corroborated in parallel experiments, using germ filtered water with and without inoculation with iron bacteria and, moreover, by microscopic observations.

The iron bacteria play a decisive part in these phenomena. However, iron bacteria play only a minor part in the establishment of anaerobic conditions under the tubercle during the main period of the corrosion (third argument).

In other words, after the tubercle has formed, corrosion (pitting) proceeds practically independent of the metabolic activity of iron bacteria.

It has been attempted to inhibit further corrosion by changing the equilibrium of the water in such a way that a compact protective layer of 'chalky rust' is formed on the surface of the 'tubercle.'

Literature

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Received August 24, 1949.

ADDENDUM

More recent studies* on the influence of polymetaphosphates on the potentials of the electrodes in differential aeration cells in running tap water, similar to those described in the preceding work, show that Calgon decreases the potential of the cathode by the formation of an adsorption layer on its surface, which inhibits the oxygen access to the iron surface with a consequent decrease of its passivation action. The potential of the anode rises because Calgon interferes with the anodic depletion of oxygen. Both these effects cause a decrease of the potential difference and of corrosion current.

On the basis of these experiments a general theory is suggested. The non-tubercle-forming and non-corrosive water has a property of the differential formation of protective layers in the areas of greater water flow, which decreases the oxygen access in these primary cathodic zones, equalizes the potentials and causes corrosion and tuberculation to stop. The differential formation of protective layers by tubercle-forming waters is very incomplete, partially as a result of the deficiency of film-forming substances and partially a consequence of the biological deposits which act either by interference with the cathodic formation of the protective layers or by very quick establishment of highly anaerobic conditions in primarily anodic areas with such a quick drop of the potential that the slower cathodic decrease following the formation of a protective layer cannot equalize the potentials and stop tubercle formation.

The behavior of zinc in the differential aeration cells indicates that corrosion of zinc-coated surfaces also could be the result of the action of differential aeration current as in the case of iron. Moreover, after some weeks, zinc becomes cathodic to iron in the DA-cell where the zinc surface is exposed to an aerated water stream and the iron electrode placed in stagnant water. That explains the tuberculation and pitting in galvanized iron pipes in the same way as previously described for iron.

WACLAW SZYBALSKI, West Chester, Pa.,
September 30, 1950

* J. L. Mansa and W. Szybalski. Corrosion Due to Tuberculation in Water Systems. I. The Influence of Calgon on the Potential of Iron Electrodes in Differential Aeration Cells With Running Tap Water. II. The Effect of Calgon on the Potential of Zinc and Copper Electrodes in Differential Aeration Cells with Running Tap Water. Danish Academy of Technical Sciences, Section of Pipe Corrosion. Inter. Reports No. 34 and 35. Copenhagen, February, 1950; and *Acta Chemica Scandinavica* (in press).

ERRATA—*Corrosion*—Vol. 6 and 3

(These corrections are printed in conformity with the American Standards Association recommendations for the publication of errata in such a way they may be clipped from this page (which is blank on the reverse side) and pasted over the areas in which the errors appear.)

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Reference:
Hoxeng, R. B.—Electrochemical Behavior of Zinc and Steel in Aqueous Media—Part II. Vol. 6, No. 1, 308-12 (1950) Sept.

p 308, col 2, line 10

silicates can also decrease the probability of reversals

p 309, col 2, lines 30-31

trode potential is temperature dependent. One is tempted to look for an analogy in the corrosion

p 311, col 2, line 4

ppm HCO_3, 10 ppm SO_4 and 0, 8 and 16 ppm Si O_2,

p 312—Caption to Figure 8, line 4

C, 50 ppm HCO_3, 20 ppm SO_4, 10 ppm Ca, 8 ppm SiO_2; Curve D, 50 ppm HCO_3, 20 ppm SO_4, 8 ppm SiO_2.

•

Reference:
Sawyer, D. W., and Brown, R. H. Resistance of Aluminum Alloys to Fresh Waters. Vol. 3, No. 9. 443-456 (1947) Sept.

p 444, Table I, left hand column

For "chlorine" substitute: Chloride

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Compiled by

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Five-Year Index

To

Technical Articles

PUBLISHED IN

Corrosion

OFFICIAL PUBLICATION
NATIONAL ASSOCIATION OF CORROSION ENGINEERS
HOUSTON, TEXAS

1945 Vol. 1 THROUGH 1949 Vol. 5

PUBLISHED IN DECEMBER, 1950

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History of Index

(1) The project of originating a topical index under which abstracts dealing with corrosion can be classified was begun by the NACE Abstract Committee in January, 1947, under the chairmanship of Mrs. Lorraine Voigt Peloubet. This index, in the revision dated November, 1950, is the one used herein for the purpose of cross-indexing only the technical articles published in CORROSION in the years 1945-49 inclusive.

Description of Index

(2) First column of the tabular index contains the titles and authors of technical articles published in CORROSION arranged chronologically by years and months (Volumes and Issues) and the number of the page on which the listed article begins. Discussions are listed only when separated from the article to which they refer. Each of the eight major columns to the right is numbered to correspond to the primary subject in the topical index. Within each of the major columns are numbered columns corresponding to the sub-topic or secondary subject of the topical index. When the subject matter of an article falls into the topic indicated by any of the first two index numbers, a check mark is placed in the column. Under the alphabetical index of authors, each author's contributions are indexed by years and page number.

How to Use Index

(3) To discover the subject matter of a known article, first find the article in the left hand column, search horizontally to the check mark(s), then up to column headings to learn the secondary and primary topical classification numbers; then refer to the list of topics to learn the topics corresponding to the numbers. To search for a topic in an unknown article, first refer to the list of topics and note the two numbers corresponding to the topic. Refer to the column headings of the table, find the major and minor columns corresponding to the number, and trace down vertically until a check mark is reached, then search horizontally to the title of the article to which the check mark refers.

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Compiled by the Abstract Committee, National Association of Corrosion Engineers

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CORROSION CONTROL
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Topic of the Month

Concrete Lining of Cast Iron Lines For Sea Water Service

By T. S. MOFFATT, JR.*

MAINTAINING high carrying capacity and the control of internal corrosion are always major problems in operating water lines. In process industries using sea water, the problem is aggravated by the extremely corrosive nature of the water, resulting in the rapid formation of very large masses of rust tubercles, and by the growth of marine fouling organisms on the internal surface of the pipe. The marine growths can be effectively controlled by chlorination of the water at the intake but more elaborate means must be employed to combat the effects of the corrosion.

At the Southern Alkali Corporation plant at Corpus Christi, Texas, 50,000,000 gallons of sea water per day are pumped for cooling purposes through a system consisting of one 30-inch and one 36-inch line, each about 1000 feet long, one 24-inch lateral about 500 feet long and about 500 feet of miscellaneous short 24-inch laterals. The 36-inch line is 12 years old and the rest are 16 years old. All are cast iron and, when installed, were lined with coal tar enamel. These lines have been cleaned three times in the past with a National Water Main Cleaning Company cleaning tool of the type shown in the illustration. This device is placed in the line and is propelled by the pressure of the water behind it. This operation removes most of the accumulated tuberculation and temporarily restores the lines to approximately their original carrying capacity; however, such cleaning does nothing to deter the subsequent re-formation of the heavy deposit of tuberculation nor to check the continuing progressive destruction of the pipe by this attack.

In order to eliminate the need for periodic cleaning, and to halt the destructio nof the lines by tuberculation, the system was recently lined with cement mortar by the "Centriline" process. In addition to other advantages, such a lining restores the carrying capacity to approximately that of new pipe and reinforces spots damaged by deep localized corrosion attack.

Preparation for the application of cement lining consists of cleaning with the cleaning tool, followed by hand scraping. The lining is applied by the "Centriline" centrifugal lining machine shown in the illustration. In this machine, the mortar which is mixed above ground, is fed from a hopper by a worm feed into a rapidly revolving dispensing head from which it is thrown centrifugally at high velocity onto the pipe wall. The thickness of coating (3/16-inch in this case) is controlled by the rate of travel of the machine through the pipe. The coating is smoothed out by slowly revolving trowel arms mounted on the machine behind the dispensing head. The operation results in the application of a smooth, uniform and dense lining.

It is believed that with proper control over fouling growths by chlorination, little or no cleaning will now be required to maintain good carrying capacities in these lines. Comparison of two sets of measurements, one made immediately after lining, and another six months later, showed no decrease in carrying capacity during that period. Furthermore, the elimination of sea water attack on the interior of the lines should add years to their useful life.

*Chemical Engineer, Southern Alkali Corp., Corpus Christi, Texas.

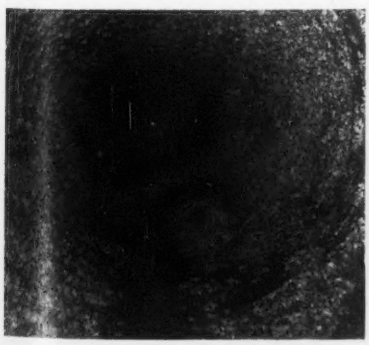

Figure 1—View of one of the lines before cleaning.

Figure 2—Cleaning tool.

Figure 3—Lining machine, shown placing lining in a short section of pipe which was removed to provide access to balance of underground line.

NACE News

Formation of Two New Sections Is Underway Now

Detroit Group Meets To Organize Section

First meeting of a group of Detroit engineers interested in corrosion to form a Detroit Section of the National Association of Corrosion Engineers was scheduled December 7, 1950, at Engineering Society of Detroit. Engineers and industrial concerns active and interested in the corrosion field are asked to communicate with one of the following:

Norman Kerstein, Detroit Edison Research Staff.

J. H. LoPrete, Spray Coat Engineers, 8711 W. Chicago, Detroit, Mich.

James Cogshall, Penn Salt Company, Wyandotte, Mich.

L. D. Cook, Wyandotte Chemicals Co., Wyandotte, Mich.

Preliminary plans for organization of the section were made at a dinner meeting held at the Rackham Building.

M. C. Miller Moderates Discussion in New York

M. C. Miller of Ebasco Services acted as moderator at a round table discussion on cathodic protection at the November 8 meeting of Metropolitan New York Section of Building Trades Employers' Association, 2 Park Ave., New York City. Ninety-two members and guests were present.

The nominating committee submitted names of candidates scheduled to be elected by letter ballot results of which are due December 6.

R. H. Brown of Aluminum Company of America spoke on "The Electrochemical Fundamentals of Corrosion" at the September 20 meeting of Metropolitan New York Section. His talk covered the role of polarization and was followed by more than an hour of discussion from the floor.

T. P. May, section chairman, announced the section's by-laws had been accepted by regional officers.

Philadelphia Section

The Philadelphia Section meets December 12 at the Poor Richard Club for its annual Christmas party. F. L. LaQue, of The International Nickel Co., Inc., New York City will be guest speaker on the subject "Advantages and Limitations of Different Methods of Corrosion Testing."

NACE CALENDAR

December

6—North East Region Trustees.
Metropolitan New York Section.
12—Chicago Section. Guest speaker, Vance N. Jenkins, NACE President.
Houston Section.
13—Philadelphia Section. Christmas Party.
Poor Richard Club.
18—Greater St. Louis Section. Panel Discussion: Dean L. E. Stout, Washington University Moderator. Panel Members, W. H. Keller, Mallinckrodt Chemical Co.; L. D. McCoy, Monsanto Chemical Co.; C. M. Blair, Tret-O-Lite Co.; R. D. Rodrian, C. K. Williams Co.; A. W. Wolff, National Carbon Division, U.C.C.
20—Los Angeles Section.

Corrosion
News Deadline:
10th of Month
PRECEDING
Date of Issue

Baltimore Section

"Studies in the Corrosion of Iron," by Walter A. Patrick, Johns Hopkins University, will be the principal item on the scheduled November 21 meeting of Baltimore Section at Park Plaza Hotel, Baltimore. Dinner will begin at 6:45 p.m.

Dr. Patrick, best known for his discovery and development of silica gel, has a nation-wide reputation for pioneering in various chemical fields.

BRUCHARD F. HEYE

Bruchard F. Heye, chief chemist and research engineer for Central Power and Light Company, Corpus Christi, was killed instantly at 1 p.m. November 5 when the car in which he was driving alone over an unpaved road was hit by a passenger train near Victoria, Texas. He is survived by his widow, two children, two grandchildren, his parents and a brother.

He was a member of NACE and chairman of the Corpus Christi Section program committee.

New Orleans-Baton Rouge Section Meeting Held

Temporary officers have been named for a New Orleans-Baton Rouge, Louisiana Section of NACE, and a letter of charter application has been forwarded to. T. F. P. Kelly, regional chairman, requesting recognition as a local section. Temporary officers appointed are: Chairman, Clifford L. Barr, Shell Oil Co., Richards Bldg., New Orleans, La.; Vice-Chairman, A. F. Blumer, Esso Standard Oil Co., Route No. 1, Ethel, La.; and Secretary - Treasurer, Lloyd L. Sevin, Louisiana Power & Light Co., 142 Delaronde St., New Orleans 14, La.

The meeting will be held November 20, beginning at 7 p.m. at Club Tropicano, Baton Rouge, La. Speakers following the dinner will be C. R. Draughan and E. R. MacNeil, who will discuss "Cathodic Protection of Open Tank Cooler."

This is the twentieth section organization of NACE and the ninth of the South Central Region.

Planning of Ladies' Conference Program Events Accelerated

Mrs. Beatrice Bailey a special representative for Consolidated Edison Company of New York has assumed responsibility for planning activities for the ladies attending the 1951 NACE "March in New York" Annual Conference. Organization of the Ladies' Committee has been placed in her hands and she is expected to solicit the assistance of other ladies of the Association.

At the first meeting of the Local Arrangements Committee attended by Mrs. Bailey she presented comprehensive plans for entertainment, including a visit and tea on a modern trans-Atlantic liner, a fashion show sponsored by a leading New York shop and a trip to a session of the United Nations at Lake Success. Other scenic and entertaining trips may be arranged to suit the desires of the guests.

Details of many interesting entertainment features will be revealed later, and reservations for each event may be made as part of the advance registration planned during January.

•

Advance notices of meetings of organizations other than NACE engaged in corrosion work will be published on request in the "Meetings" column.

Materials Selection Is Gosnell's Topic

Selection of materials useful in handling corrosive chemicals, such as fatty acids, mineral acids, alkalis and others was discussed in an address by Everett C. Gosnell, vice-president Colonial Iron Works, titled "Process Chemical Corrosion Problems and Solutions by Selection of Materials and Design of Equipment," November 20 before Greater St. Louis Section NACE. Modern equipment design and fabrication methods were covered in detail and economy in equipment cost was stressed.

The speaker, after obtaining an MA in chemical engineering from Indiana University in 1927 spent some years at Seaboard Experiment Station working on corrosion problems for the Koppers Co. Afterwards, with International Nickel Co., he worked on corrosion problems and process design. From 1937 to 1946 he was with Lukens Steel Company as manager of its chemical equipment division and since 1946 has been vice-president in charge of the Chemical and Process Equipment Division of Colonial Iron Works.

He is a charter NACE member, and is besides a member of ASC, AIChE, AWS, Alpha Chi Sigma and the Cleveland Engineers Society.

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News about the activities of organizations anywhere in the world engaged in corrosion mitigation are welcomed for use in the news section of CORROSION.

"Corrosion Resistance of Special High Alloy Materials" Is Topic at St. Louis Meeting

Greater St. Louis Section at its October 16 meeting heard Glen A. Fritzler of Haynes-Stellite Division of the Union Carbide and Carbon Corp. present a paper "Corrosion Resistance of Special High Alloys Materials."

Mr. Fritzler's remarks are summarized as follows:

During the last two decades many additions have been made to the family of corrosion resistant materials of particular interest among which are alloys of austenitic nature which possess stainless and super-stainless characteristics. The higher alloyed materials also have entered this field recently as alternates to pure metals. Some of these alloys are complex iron, nickel and cobalt-base alloys containing chromium, molybdenum, tungsten, columbium, tantalum, copper, silicon, etc. The commercial alloys are described and classed in two groups according to their principal mechanism of corrosion resistance.

Solution Potential Important

Work at the National Bureau of Standards and the research laboratories of the Aluminum Company of America with aluminum alloys has revealed interesting relationships between solution potential measurements and corrosion characteristics. This method of evaluation seemed well-suited for application to the stainless-type alloys, so in 1946 an investigation of the solution potential properties of four high alloys was initiated. They were No. 5 (Mastelloy B), No. 6 (Hastelloy C), No. 12 (H.S No. 21) and No. 21 (N-155). The speciments used were ¼-inch in diameter by five inches long wrought bar stock. The specimens were polished to a fairly fine

(Continued on Page 4)

Shown here at the October 16 meeting of Greater St. Louis Section are: G. A. Fisher, program chairman; Glen A. Fritzler, speaker; F. L. Whitney, Jr., section chairman, and C. A. Swartout, section secretary.

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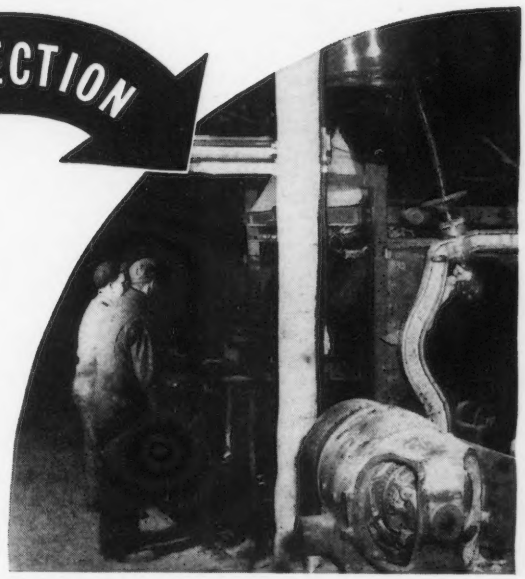

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Baumstark Is Named Treasurer at St. Louis

Walter A. Baumstark, The Carpenter Steel Co., has been named treasurer of the Greater St. Louis Section, NACE succeeding George E. Purdy, who resigned upon being transferred from the St. Louis area. Mr. Baumstark will serve for the remainder of the 1950-51 term.

About forty persons attended the September 18 meeting of the section opening the 1950-51 season. George Fisher presented the schedule of programs, which covers many fields. The technical program consisted of two motion pictures, "Corrosion" and "Corrosion Proof."

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Advance notices of meetings of corrosion interest should be sent to CORROSION in sufficient time to permit publication in an issue distributed before the meetings are held.

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Corrosion Resistance—

(Continued from Page 3)

finish and an attempt was made to make all specimens and tests as nearly identical as possible in several solutions as follows: 10 percent solutions of sodium chloride, magnesium chloride, hydrochloric acid, sodium sulfate, nitric acid and a combination of 10 percent sodium chloride and 5 percent ferric chloride. All solutions were at room (25 to 30 degrees C) temperature and the percentages represented are "by weight".

The measurements, expressed in volts, were determined with a Beckman pH meter. Because this instrument has high internal electrical resistivity, it consumes virtually no current and consequently has little influence on the test cell. This is an important point in testing high chromium alloys whose passive films might be affected even by small amounts of current passing in or out of the test cell. The Beckman pH meter was capable of measuring 0.0025 volts, but recorded readings were made to the nearest 0.01 volt for this work.

Method is Outlined

The reference cell was a saturated calomel cell with an accepted value of 0.264 volt in relation to the hydrogen electrode. The electrode made electrical contact with the test solutions through a very slightly porous glass tip so that practically no contamination of the test cell resulted from the potassium chloride solution in the calomel cell.

The values are designated as plus (+) or minus (—) in comparison to the calomel electrode. A minus (—) value shows that the alloy is less noble to a particular solution than the reference electrode, and the plus (+) value shows that it is more noble. Thus, relative tendencies of alloys to dissolve in a particular medium are determined: i.e., an alloy with + voltage is more noble than another alloy with — voltage in a specific solution.

The test solutions were open to the air. The portion of the specimens exposed at the air-liquid interface was coated with paraffin, so that samples could be moved without exposing fresh surfaces during the test. Measurements were made soon after immersing the sample, and to determine the effects of time of exposure on the tendency of an alloy to dissolve, also at intervals for periods of either 96 or 144 hours.

The following table presents data for the alloys in a 10 percent sodium chloride solution and for six other test solutions previously listed:

Relative Solution Potential Values (Volts) for Alloys:

SOLUTION	Hours*	B	C	No. 21	N-155
Sodium Chloride	i	—.39	—.26	—.20	—.12
10 percent by Weight	1	—.39	—.09	—.03	+.04
	10	—.44	+.15	+.22	+.23
	50	—.40	+.22	+.26	+.22
	100	—.38	+.21	+.29	+.13
Mangnesium Chloride	i	....	....	....	....
10 percent by Weight	1	....	....	....	....
	10	—.39	+.02	+.05	+.03
	50	—.40	+.16	—.08	—.09
	100	—.39	+.18	—.09	+.24
Hydrochloric Acid	i	—.11	—.03	—.21	—.23
10 percent by Weight	1	—.07	—.11	—.28	—.28
	10	—.07	—.11	—.28	—.28
	50	—.07	—.13	—.28	—.27
	100	—.07	—.13	—.28	—.27
Sulfuric Acid	i	—.09	+.03	—.04	+.03
	1	—.05	+.10	+.07	+.09
	10	—.06	+.12	+.13	+.12
	50	—.06	+.13	+.28	+.24
	100	—.05	+.13	+.30	+.28
Nitric Acid	i	—.02	+.18	+.43	+.35
	1	—.01	+.17	+.37	+.22
	10	0	+.18	+.51	+.36
	50	+.05	+.17	+.60	+.47
	100	+.08	+.17	+.64	+.64
Sodium Sulfate	i	—.47	—.10	+.05	—.03
	1	—.49	0	+.12	+.09
	10	—.50	+.01	+.13	+.10
	50	—.49	0	+.10	+.11
	100	—.47	—.04	+.06	+.12
Sodium Chloride (10 percent	i	+.10	+.53	+.59	+.47
Plus	1	+.06	+.42	+.63	+.49
Ferric Chloride (5 percent)	10	+.04	+.45	+.63	+.35
	50	+.01	+.49	+.63	+.21
	100	—.04	+.52	+.63	+.16

*i = on immersion.

Producing Company's Corrosion Program Is Houston Section Topic

H. L. Bilhartz, Atlantic Refining Co., Dallas, Texas, addressed 52 members and guests of Houston Section November 14 at Guy Francis' Restaurant, Houston on "A Producing Company's Corrosion Research Organization." Mr. Bilhartz, who is chairman of NACE Technical Practices Sub-Committee TP-1C outlined his company's approach to the identification and evaluation of corrosion problems and the resulting coordinated effort of the mechanical engineer, operating engineer and field personnel to solve problems economically. Emphasis was placed on the importance of good relations between the corrosion engineer with operating personnel and top management.

Prior to Mr. Bilhartz' address, the section heard Thomas E. Willier, Director of Traffic and Transportation of the City of Houston discuss the traffic problems of a growing city. This topic was in keeping with a new plan by the section's program committee intended to broaden programs by providing able, non-technical coffee speakers.

Scheduled plans for the December 5 meeting call for a joint session with the local ASM group at the Ben Milam Hotel. John J. Halbig, active as an NACE member and as a member of technical committees, Armco Steel Corp., Middletown, Ohio, will discuss new developments in stainless steels.

Boiler Feedwater Is New '51 Symposium

A Boiler Feedwater Symposium, cosponsored by the Subcommittee on Corrosion of the Joint Research Committee on Boiler Feedwater Studies has been substituted for the Food Industry Symposium included in the scheduled technical program for the 1951 Conference in New York City, March 13-16.

Mr. I. B. Tietze of Phillips Petroleum Company has taken over the chairmanship of the Pipe Line Industry Symposium and the symposium has been moved to Tuesday afternoon, concurrent with the Water Industry Symposium. The Boiler Feedwater Symposium has been scheduled for Wednesday morning, concurrent with the Chemical Industry Symposium.

All other elements in the technical program will remain as previously scheduled tentatively and as reported on Page 4 of the August 1950 issue of Corrosion.

MEMBERSHIP CARDS AVAILABLE

Association members in good standing will be issued on request a membership card in the National Association of Corrosion Engineers. Address requests to A. B. Campbell, Executive Secretary, 919 Milam Building, Houston 2, Texas.

Progress Is Reported By '51 Conference Arrangements Group

Reports of the activities of the nine groups comprising the Local Arrangements Committee were presented to H. L. Hamilton, chairman, at a meeting November 2 at Hotel Statler, New York City, where the 1951 NACE "March in New York" Conference and Exhibition will be held March 13-16.

Hamilton

Of importance was the introduction of Mrs. Beatrice Bailey, heading the Ladies' Committee, and the presentation of her plan for a comprehensive program of entertainment for ladies attending the conference.

Linden Stuart, Jr., chairman of the Entertainment committee reported on plans for the Fellowship Hour and banquet. Admission to the Fellowship Hour will be by ticket to be issued at the time of registration. Entertainment for the banquet will be by talent noted on Broadway and attention was called to the fact attendance must be limited to 500.

M. Bermann, chairman of the Transportation Committee reported airlines and railroads are planning through regional offices to make direct contact with every NACE member, furnishing schedules and other information.

Reports of the Technical Program and Exhibition Committees were received by L. B. Donovan, general conference committee chairman.

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"Fundamentals of Galvanic Corrosion" by A. B. Lauderbaugh, The Manufacturers Light and Heat Co., Pittsburgh, Pa., a paper presented at the Distribution, Motor Vehicle and Corrosion Conference, Detroit, Mich., April 3-5, 1950 of the Operating Section of the American Gas Association has been reprinted by Dowell Incorporated.

Vinal Is Awarded Acheson Medal, Prize

Dr. George Wood Vinal, retired Chief of the National Bureau of Standards' Division of Electrochemistry and dean of the NBS staff has been selected as the eleventh recipient of the Electrochemical Society's Edward Goodrich Acheson medal and prize. The award, a gold medal and $1000 prize is conferred biennially for the most outstanding contribution in the fields of activity fostered by the society.

Defective October Copies Replaceable

Upon notice by those who have received them, Central Office NACE will replace defective copies of the October issue of Corrosion. Several reports of the receipt of defective copies have been received. These copies will be replaced as long as the supply of perfect copies at Central office lasts, and without cost to members and subscribers.

CORROSION DIRECTORY

Rates for notices under this heading can be obtained from National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas

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South East Region Fall Meeting Held

South East Region's nominating committee submitted to the semi-annual regional meeting at Birmingham, Ala., November 8 the following nominations for officers:

For chairman: E. P. Tait, Alloy Steel Products Co., Atlanta, Ga.

For vice-chairman: R. A. Davis, Chicago Bridge and Iron Company, Birmingham, Ala.

For regional director (one to be named): E. C. Range, Okonite Co., Atlanta, Ga., and A. R. Swanson, American Telephone and Telegraph Co., Atlanta, Ga.

For secretary-treasurer: H. C. Van Nouhuys, Southeastern Pipeline Co., Atlanta, Ga.

For membership chairman: Jack West, Aluminum Co. of America, Atlanta, Ga.

For program chairman: H. W. Dent, Jr., American Cast Iron Pipe Co., Birmingham, Ala.

For by-laws chairman: E. D. McCauley, American Cast Iron Pipe Co., Birmingham, Ala., and E. C. Pritchett, American Telephone and Telegraph Co., Atlanta, Ga.

Twenty-four members and fifteen guests attended the semi-annual meeting and A. B. Campbell, NACE executive secretary, was dinner speaker.

Three technical papers and a dinner address and discussion by A. B. Campbell, executive secretary of NACE about the association are the scheduled items on the program for the fall meeting of South East Region at Birmingham, Ala., November 8.

Technical papers scheduled to be given are: "Cathodic Protection of Uncoated Steel Pipe in City Distribution," by Sidney E. Trouard, New Orleans Public Service Corp.; "Properties of Graphitization in Cast Iron," by James T. MacKenzie, American Cast Iron Pipe Co., Birmingham, Ala., and a paper on corrosion problems in the textile industry.

New Officers Are Named at Shreveport

T. L. Holcombe, acting secretary of the Sheveport Section NACE was elected to fill the office of vice-president, when this office was vacated by resignation of Joe Creevy. J. W. Smith was named secretary to replace Mr. Holcombe. These elections and a report on the September corrosion course successfully given by the Shreveport Section were features of a section meeting October 21 at the Caddo Hotel, Shreveport.

Concern over dwindling attendance at Shreveport Section meetings was expressed by T. L. Holcombe, and various means of improving it were discussed by Messrs. Spinks, Moncreif, McMann and Sullivan. Mr. Sullivan proposed that dinner meetings be suspended at discretion of the program chairman. Chairman H. V. Beezley will name a committee to study attendance problems. Among the proposals advanced to increase interest was that by Mr. Farmer who suggested an earlier meal time, prompt starting of the meeting and a diversification of subject matter presented at the meetings to attract other than the pipe line group.

"Corrosion Hazards in Petroleum Production," was the title of a paper presented by Ed Greco. Mr. Greco pointed to the loss of life as well as property from oil and gas production operations.

South Central Officers

A letter ballot has been mailed members of South Central Region for new officers of the region. Officers named on the ballot nominated by the nominating committee of the region are as follows: For chairman, George A. Mills; For vice-chairman, M. C. Fleming; For secretary-treasurer, Harry E. Waldrip and for assistant secretary-treasurer, John G. Campbell.

Corpus Christi Section

C. R. Williams, vice-president and general manager of Chicago Corporation was the scheduled speaker at an October 25 meeting of Corpus Christi Section, NACE held at White Plaza Hotel. Mr. Williams' talk was directed to both the engineers and to management in an effort to interest more companies in corrosion control.

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St. Louis Meetings for Nine Months Scheduled

A nine-month schedule of meetings by Greater St. Louis Section NACE has been prepared covering the September-May period as follows:

September 18—Motion pictures, "Corrosion" and "Corrosion Proof," Allegheny-Ludlum Steel Co.

October 16—F. E. Badger, Vice-president and Director of Research, Haynes-Stellite Co., "Corrosion Resistance of High Alloy Materials."

November 20—Everett C. Goznell, Vice-president Colonial Iron Works, "Process Chemical Corrosion Problems and Solutions by Selection of Materials and Design of Equipment."

December 18—Panel Discussion, Dean L. E. Stout, Washington University, moderator. Panel: Dr. W. H. Keller, Mallinckrodt Chemical Co., L. D. McCoy, Monsanto Chemical Co.; Dr. C. M. Blair, Tret-O-Lite Co.; Dr. R. H. Rodrian, C. K. Williams Co., A. W. Wolff, National Carbon Division, Union Carbide and Carbon Corp.

January 15—Kenneth Tator, consultant, Coraopolis, Pa. "Corrosion Control and the Role of Protective Coatings."

February 19—C. P. Larrabee, Carnegie-Illinois Steel Co., "Corrosion of Steels as Related to Environment and Composition."

March 19—A. H. Reynolds, Director of Product Development, Dearborn Chemical Co., "The Importance of Inhibited Compounds in the Preservation of Materials Consumed by Corrosion."

April 19—Kent R. Van Horn, Associate Director of Research, Aluminum Company of America, "Industrial Application of Aluminum." Joint AIChE and Engineer's Club meeting.

May 21—Leo F. Collins, Detroit Edison Co., "Effect of Water Treatment on Corrosion in Heat Exchanger Equipment."

Vance Jenkins Talks At Los Angeles Meeting

Vance Jenkins, president of NACE reported briefly on the activities of his office and plans for the New York Conference March 13-16, 1951, at a Los Angeles Section meeting October 20. He announced that the abstract card file service soon will be ready to start functioning at a cost of about $75 a year to subscribers.

I. C. Dietze reported formation of Technical Practices Committee 16 on Corrosion of Cable Sheaths.

E. O. Kartinen of Signal Oil and Gas Company spoke on "Combating Corrosion in the Oil Industry" and showed a motion picture "Drilling for Oil," substituting for the scheduled speaker who was unable to be present.

A round table discussion on cathodic protection also was held with a panel consisting of Dr. Gordon Scott, consultant and H. J. Keeling and W. M. Schilling of Southern Counties Gas Company. The discussion had to be cut short because of lack of time.

The dinner meeting at Rodger Young Auditorium was attended by 45 members and 15 guests.

Loy L. Flor of LaMesa, Lemon Grove and Spring Valley Irrigation District reported further on carbon anodes excavated. Salt lasted for three years around the anodes. Dr. Scott said that the presence of free sulfur around the anodes could not be accounted for, but was probably not harmful. Dr. Pomeroy that perhaps H_2S was present in the soil and had been oxidized at the anode. HSO_3 may accelerate corrosion of the anode.

D. A. Blackburn of the Pasadena Water Department commented on the failure in 1935 of some of the lead connections in water mains. The interior was full of small craters and was highly colored, as if by heat. Among the causes suggested was that perhaps there had been an arc as a result of power failure. Mr. Keeling and Mr. Jones stated rectification occurs on both lead and iron, causing AC corrosion in the presence of their oxides.

W. M. Schilling displayed several sets of corrosion coupons removed from pipe lines. Dr. Scott questioned the accuracy of test coupon data because of the potential difference between rusty and bright steel. It was stated, however, that these coupons are used only to compare protected and unprotected weight losses.

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Notices of meetings to be held by NACE subdivisions will be carried in the "NACE Calendar" if received in time.

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NACE Nominating Committee Reports; Members Are Mailed Data on Elections

A report of the National Association of Corrosion Engineers' nominating committee for officers and directors of the national organization was mailed to membership November 15, together with several exhibits giving full information about procedure, qualified and unqualified members for various offices, copies of Articles IV and VIII of the association's articles of organization, and a schedule of dates related to the election of national officers. A. B. Campbell, executive secretary, urged members to consider all of the exhibits in the mailing so that any action taken may be according to the provisions of the articles of organization.

The NACE nominating committee's report named the following list of candidates for offices:

For president: N. E. Berry, Servel, Inc., Evansville, Ind.

For vice-president: M. G. Fontana, Ohio State University, Columbus, Ohio and M. J. Pearson, Sun Oil Co., Newton Square, Pa.

For treasurer: R. A. Brannon, Humble Pipe Line Co., Houston, Texas.

For director representing active members (one vacancy to be filled): J. Pat Casey, Jr., The Crane Co., Chicago, Ill., and R. B. Hoxeng, Case Institute of Technology, Cleveland, Ohio.

For directors representing corporate members (two vacancies to be filled): H. R. Brough, Mountain Fuel Supply Co,. Salt Lake City, Utah; R. H. Coe, Pittsburgh Coke & Chemical Co., Pittsburgh, Pa.; C. P. Larrabee, Carnegie-Illinois Steel Corp., Vandergrift, Pa.

Nominations May Be Made

Nominations of candidates in addition to those named by the nominating committee may be made on petition signed by 25 members. Nominations made under under this rule must be in the hand of A. B. Campbell, executive secretary, Central Office NACE, on or before December 20.

The nominating committee is restricted to naming not more than two candidates for each office. There is no restriction on the number that may be named by petition. Nominees by petition will be added, in alphabetical order, to the letter ballot to be mailed all members.

Schedule of Events

The following schedule is pertinent to the nomination and election of 1951 national officers: (Dates are for completion).

Formation of nominating committee, September 15, 1950.

Six weeks' interval for nominating committee to nominate candidates and make report, October 27, 1950.

Maximum of 35 days for members to prepare and file nominations by petition, December 20, 1950.

Preparation and mailing of letter ballots to NACE members, January 15, 1951.

Period allowed for members to return letter ballots, February 20, 1951.

Period allowed to count ballots and prepare report by tellers, March 1, 1951.

General business meeting, March 13, 1951.

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Reports of meetings of subdivisions of NACE should be sent to Central Office in sufficient time to meet the publication deadline of the tenth of the month preceding date of issue.

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Numerous Association Activities Recorded in 1950

A high level of activity and marked progress in several areas was registered by the National Association of Corrosion Engineers during the calendar year 1950. Principal gains were in three new organized sections, those at Los Angeles, Calif., the Houston, Texas, University of Houston Section (first student section) and Western New York Section, at Buffalo. Perfection of a new section for New Orleans-Baton Rouge in Louisiana is now under way and completion of preliminary organization is looked for before the end of the year.

Additions also have been made to the Technical Practices Committee subdivisions. Added sub-committees this year are TP-16—Electrolysis and Corrosion of Cable Sheaths; TP-17—Standardization of Procedures for Measuring Pipe Coating Conductance and TP-18—Internal Corrosion of Facilities for Storage and Transportation of Petroleum. Existing sub-committees have added subdivisions as follows: TP-6K—Chemical- Resistant Masonry Construction. Publication of the designations of the technical practices committee subdivisions, together with chairmen was made a monthly feature of Corrosion beginning in April.

Reports Published

Reports of technical committees have been published during the year as follows: First Interim Report on Galvanic Anode Tests. (Publication 50-2) TP-2. First Interim Report on Ground Anode Tests. (Publication 50-1) TP-3. First Interim Report on Recommended Practices for Surface Preparation of Steel. (Publication 50-5) TP-6G. Report of TP-1 on 32 Alloys in Seven Condensate Wells has been approved for publication but has not yet been issued. (Publication 50-3) A Directory of membership of Technical Practices Committees was published. (Publication 50-4.)

Short Courses Held

Several short courses have been held during the year. The first of these, sponsored by Tulsa Section, was held February 20-23 with 178 registered. Shreveport Section sponsored a pipeliners' school September 13-15 and Case Institute of Cleveland held a short course September 25-29 at which 201 were registered. Stevens Institute at Brooklyn is offering a course in corrosion both semesters this year which may be attended for credit or not and at the University of California in Los Angeles a similar extension course is being held this year.

Regional Meetings

Regional meetings including scheduled technical sessions were held by South East Region at Atlanta, April 14 and at Birmingham November 8. The annual South Central Regional meeting was held at Houston October 9 and 10 with 261 registered. North East Region has held several joint meetings with its sections.

The annual conference held at St. Louis April 14-17 was considered to be among the best held by the association with 942 registered.

Corrosion Course Set At Stevens Institute

"Corrosion Prevention," is the title of a course scheduled to be given at the spring semester at Stevens Institute of Technology's graduate school, Hoboken, New Jersey, in cooperation with the National Association of Corrosion Engineers, according to information supplied by R. S. MacCormack, lecturer on corrosion in the graduate school.

Topics listed include review of corrosion factors, design features, humidity control, de-aeration, inhibitors, light metal alloys, copper alloys, nickel alloys, iron and stainless alloys, alloys of lead and zinc, high temperature alloys, metal coatings, cathodic protection, paints and pigments, plastics, rubber, etc.

Class periods begin at 6:30 p.m. on Wednesdays and the public will be admitted to talks by guest lecturers beginning at 8 p.m. Guest lecturers in several fields will be presented and discussions will follow each lecture or report.

The fee for admission of the public to these talks will be $25, of which $5 may be applied toward a membership in NACE. The fee for persons members of NACE will be $20. Students will be charged the regular tuition.

•

The Galvanizers Committee of the American Zinc Institute, Inc., met at Birmingham, Ala., November 16 and 17.

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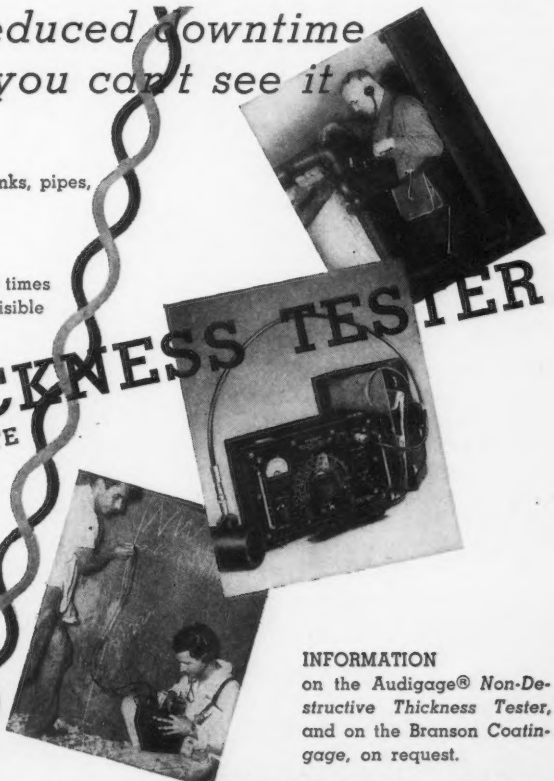

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A TOUGH CORROSIVE TEAM TO BEAT . . .

You can do it with
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Coating Aluminum

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Not just another aluminum-pigmented paint, Dampney Silicone Coating contains resins sufficient in quantity to impart to it all of the unique heat stability, low moisture absorption and exceptional durability of silicones.

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100-1 MAINTENANCE FOR METAL
THE DAMPNEY COMPANY OF AMERICA
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Tabular Cross-Reference Index to Corrosion 1945-49, Inclusive, Is Published This Issue

Incorporated in this issue of Corrosion is a separately paginated Index to Technical Material Published in Corrosion, 1945-49. The index follows immediately the index to Volume 6. The index for the five-year period, 1945-49, has been compiled to help satisfy requests repeatedly made to Central Office NACE for information relative to information which has been published. Because no index other than that published annually as part of the final issue of the year, and because no topical cross-index to the technical material has been issued by NACE it has proved extremely difficult at times to provide requested information. Frequently a time-consuming search has been necessitated because incomplete or inaccurate references are given in requests.

The tabular cross-reference is based on the first two places of the Corrosion Abstract Committee's index to corrosion abstracts, November, 1950, revision, which is published as part of the index. By arranging these topics and subdivisions in a table, it was possible at one time to give:

1. A chronological list of technical articles.
2. A list of technical articles arranged by page numbers.
3. An extensive cross-reference to each article in a relatively small space.
4. A classification by topics of all technical material published during the five years.

Use of Index

The tabular index may be used in two directions: 1) to determine what topics are covered by an article and 2) to discover what articles contain information on certain topics.

In direction 1 the procedure is to find the article in the left hand column of the table, then to search horizontally to the right where a check mark in a column indicates the topic covered by the article. Moving vertically upward in the column the second position number (sub-index number) is found; and immediately above this number is the first (or major) index number. These two numbers then are used for reference to the similarly-keyed corrosion abstract index where sub and major topics related to the numbers may be found.

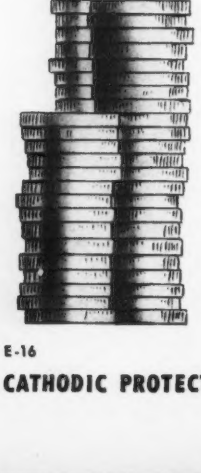
In direction 2, a reverse procedure is followed. The corrosion abstract index is consulted first. When the major and sub topic numbers have been located, the tabular portion of the table is searched. The first topic number is located, then within this topic the second or sub-index number is located. Once in the proper column, the searcher moves vertically downward until a check mark is found in the column. When a check mark is reached the searcher moves horizontally to the left, where in the left hand column may be found the title of the article, with the year, volume and page number, together with the author's name and the location of any discussions pertinent to the article which were published separately.

Author Index

An author index has been compiled in which the names are arranged alphabetically. Each author's reference includes a notation of the year and page number for each article of which he was author, and of each discussion of which he was author. Titles to articles are carried only with the name of the first author. The names of other authors than the first contain a reference to the principal author.

If sufficient demands develops, the five-year index may be reprinted.

PROFITS ARE SAVED
NOT MADE



Whether it be a gas or water distribution system, a transmission pipe line, tank bottom, off-shore drilling platform, condenser or water tank, or ship hull, corrosion losses can be stopped—*can* be converted to profits.

Electro Rust-Proofing services are designed to help you make these savings. First, ERP offers a *complete* engineering service on either a contract or per diem basis to suit your individual needs. All survey and design work is conducted by qualified cathodic protection engineers fully equipped with the necessary precision measuring instruments and other testing apparatus. Second, ERP's Contract Department is available to furnish, install and maintain all cathodic protection equipment and materials which may be required.

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Corrosion Changes in Format Aimed at Improved Utility

Several changes in content and format have been made in CORROSION during the year. The mid-year directory supplement was not published in July because of the publication monthly of lists of new members and address changes for the convenience of secretaries and others. A Directory of Technical Committees has been made a monthly feature.

The volume and coverage of news material both of association matters and of other groups, organizations and individuals active in corrosion work has been expanded. The "Corrosion Problems" feature was revived in the January issue. A new feature "Clippings on Corrosion" has been added to the news section consisting of shortened versions of news stories pertaining to corrosion from newspapers and magazines supplied by a clipping bureau. This last feature has served to illustrate the extent to which attention is being directed to corrosion in the general press and in some cases to the fact some elementary corrosion phenomena are understood imperfectly.

There were 414 pages of technical material published in 1950 (Volume 6). This is fewer pages than were published in 1949. The difference is the result in part to changed format with respect to numbering the annual and other indexes and also to the fact "Topic of the Month" has appeared as first page of the news section rather than as a part of the technical section as in the past.

Volume 6 (1950) alone contains half as many authors' names in its index as will be found in the 5-year index covering 1945-49 inclusive. The number of authors indexed for Volume 6 was 42 percent greater than the number indexed for Volume 5.

Coincident with the January issue the system of classification of abstracts published in the Corrosion Abstract section was changed. Substituted for the schedule of topics formerly used was the first two places of the Index to Corrosion Abstracts compiled by the NACE Abstract Committee. The use of this index (which was revised three times during the year) resulted in a classification of the abstracts published under the same headings as will be used for other abstract compilations by NACE. The longer list of subject headings thereby caused necessitated removing the index to the abstract section to the first page of the section. These changes, it is believed, have made the published abstracts more useful to researchers because the subject classifications now follow a proved system.

•

Photographs showing interesting corrosion problems, conditions or solutions of corrosion problems are welcomed for consideration as subjects for the cover illustration of CORROSION magazine. Photographs submitted should be accompanied by an adequate description and the necessary authority to use the photograph.

Any of these "Proven Operators"

- ✓ Westinghouse, Bendix Westinghouse
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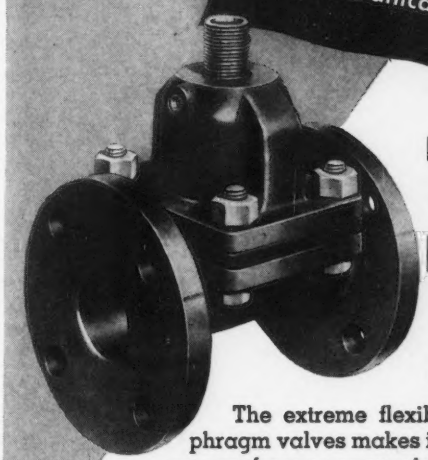

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Force-Feed Lubricators • Magnesium Alloy Castings

1951 Corrosion to Include Changes Aimed

At Closer Conformity to Periodical Standards

Several changes in format which will go into effect with the first issue of Volume 7 of Corrosion, January, 1951, have been authorized by the NACE Publication Committee after a study which was initiated at the 1950 NACE Conference in St. Louis, Mo. At that time, as a result of a number of observations which had been made to the committee respecting the necessity to conform more nearly to standard practice in format, it was decided that current practices on Corrosion would be weighed against the recommendations embodied in American Standard Reference Data and Arrangement of Periodicals, approved June 7, 1943, by American Standards Association. The consensus from those asked to give their opinion has resulted in the decision to make some changes to conform to the recommendations in the standard. Corrosion will not, however, conform completely to the recommended standard because of substantial reasons for continuing present practice.

The changes to be made effective with the January issue are:

Changes Itemized

Data for Identification: An editorial page will be the first item in the technical section of each issue. This page will include the date, volume number, and issue number. A statement identifying the last issue in each volume will be published. The sequence of information on the "spine" of the magazine will be revised to place the name of the magazine at the top, instead of as at present.

Pagination: The Corrosion Abstract section will be numbered serially through the year with Arabic numbers and the letter "a" in the lower outside margin of each page. This numbering will be in addition to the numbers now used in the upper outer margin beginning with the first page of the news section. The Corrosion Abstract section will have two numbers per page. One will be useful only in the issue and the other will be useful in those cases in which the abstract sections are bound by volumes.

The December, 1950, issue will anticipate the changes and include a page with pastable errata that can be cut from the book.

Title Page, Table of Contents and Index: In Volume 7, the separate title page, unnumbered, will be included in the December, 1951, issue. A title page for Volume 6 was printed in the January, 1950, issue immediately preceding the inside back cover.

The annual index will include monthly contents pages, a tabular cross-referenced subject index and an alphabetical author index, in that order. Each element of the index will begin on a right hand page. The index will be numbered within itself and not included in serial numbers.

In addition to these changes, most of which will be effective only with the first issue of 1951, several other changes in format have been effected during 1950:

The technical section serial numbering in each issue has ended on an even page, permitting binding of the technical section by volume.

The news section has been started in each issue with page one.

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HAERING ORGANIC GLUCOSATES*
have an unexcelled record
of performance in controlling
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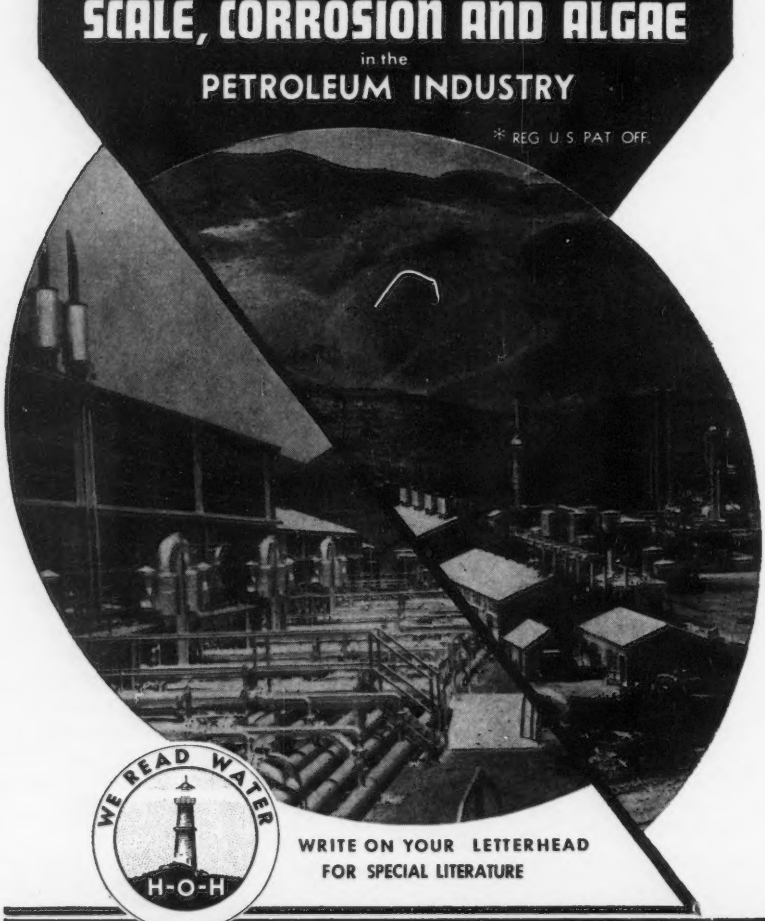

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Sellout of Exhibit Booths Is Forecast

G. E. Seidel, chairman of the Exhibition Committee reported early in November that very few exhibit spaces remained unassigned at that time. It has been necessary in a few cases to make tentative assignment of space to exhibitors requesting space already subscribed.

The number of space contracts already received exceeds that for any earlier conference, denoting a keen interest on the part of exhibitors in NACE, Mr. Seidel said.

ASM Medal Awarded

The American Society for Metal's 1950 medal for the Advancement of Research was awarded to Charles E. Wilson, president of the General Motors Corp. during the society's annual meeting at Chicago, October 23-27.

Innovations Are Made In Index to Volume 6

Several changes in the format and arrangement of the index to the technical material published in Volume 6, January-December, 1950, have been made. They conform to the decisions reached relative to changes to be incorporated in the format of Volume 7—1951. The Volume 6 index is in this (December) issue.

Each element of the index will begin on a right hand page. The index will not be included in the serial numbers of the technical section.

Elements of the index will be:

1. Technical contents by issues chronologically.
2. Tabular topical cross-reference arranged according to the NACE Abstract Committee's outline, which is published as part of the index.
3. Tabular index by issues and page numbers to the Corrosion Abstracts published in Volume 6.
4. Author's list alphabetically.

Included in the tabular cross-reference to technical material will be the "Topic of the Month" feature, although this is not included in the technical section serial numbering.

Another Revision Made Of Abstract Index

The revision of the NACE Abstract Index dated November 1, 1950 contains minor changes which apparently do not seriously disturb the status of the first two places of the revision dated July, 1950. This means that in the case of the Corrosion Abstract Section, which has been indexed under two versions of the system during 1950, no serious difficulties attend the use of the November 1, 1950 version in searching abstracts published during the year. (See Page 20, News Section, Corrosion, July, 1950 for information pertaining to the changes made in the June, 1950 version over that published in the January, 1950 issue).

Noteworthy changes as of November, 1950 were:

First two places—No major changes were made. Some of the titles have been reworded but remain substantially the same in meaning. The changes were made to clarify and simplify the index.

Third and fourth places—All classifications have been rearranged so they are in alphabetical sequence by the first letter of the first word. The exceptions to this are in the classifications "General" and "Miscellaneous" which appear first always in the lists. Some titles have been reworded for clarification and some new titles have been added.

ASTM Specifications

New and revised specifications and test methods have been approved by the American Society for Testing Materials in areas including the following: Steel, light metals, soils, simulated ocean water, hardness of metals, metallography and building constructions.

Harbor Island Addition to Kure Beach Testing Station Opened Formally Nov. 15

The new Harbor Island addition to the Kure Beach corrosion testing project near Wilmington, N. C. was opened formally November 15 and 16 with a tour attended by representatives of more than 100 industrial and government offices. F. L. LaQue, in charge of the corrosion engineering section of the International Nickel Co., Inc., under whose direction the project is operated said the additions have provided facilities for the study of more than 20,000 specimens of all types of materials in sea water and air. The testing station is believed to be one of the largest projects of its type in the world.

The sea water tests were located originally at Kure Beach in 1935 and were removed this year to the new station about 20 miles north. The atmospheric testing lot, covering an acre and a station about 80 feet from the shore line for testing the effects of sea water spray, remain at Kure Beach.

Among the specimens being tested are metals and alloys, non-metallic materials, protective coatings of all kinds and even rope. Information of data accumulated on corrosion is freely exchanged among competitors participating in the tests. Much of the research at both locations is directed toward solution of problems for the United States government.

•

Photographs showing interesting corrosion problems, conditions or solutions of corrosion problems are welcomed for consideratin as subjects for the cover of CORROSION magazine. Photographs submitted should be accompanied by an adequate description and the necessary authority to use the photograph.

Improved Paint Remover Is Formulated by Dow

Dow Chemical Company has modified a non-flammable, flush-off paint remover formulation to make it less corrosive to steel, tin-plated steel and aluminum alloys; more stable and without objectionable vapors during preparation from ethylamine, which has been eliminated, according to Chemical Industries July, 1950, issue. The formula, which already has been adopted by several large manufacturers, raises all common point, varnish and lacquer films in 1 to 10 minutes, permitting flushing with water.

Designated Formulation D-316-14A by Dow, the new formula follows:

Methylene chloride, PRG	71	gal.
Carbon tetrachloride	6	gal.
Methanol	12	gal.
Di-triisopropanolamine, PRG	9.5	gal.
Water	1.5	gal.
Areskap 100 (Monsanto Chemical Co.)	33	lb.
Potassium oleate	22	lb.
Paraffin (47-50.6° Cmp)	16.5	lb.

To prepare the product, carbon tetrachloride is added to the methylene chloride, and then the paraffin is melted and dissolved into this mixture with agitation. Methocel is added and stirred until completely wetted out. Methanol is added slowly and stirred until Methocel is completely dispersed. Potassium oleate and Areskap 100 are added. The di-triisopropanolamine mixture is added, and finally the water.

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Only Federated gives you magnesium anodes with:

Integrated Core . . . an electro-galvanized, full-length, spiral-wound strip core perfectly bonded to the magnesium alloy . . . assures continuing operation.

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Corrosion Problems

Questions and answers for this heading should be submitted in duplicate if possible, addressed to "CORROSION PROBLEMS", National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas. Questions received at the address above above will be sent to E. A. Tice, The International Nickel Co., Inc., N. Y., who is acting editor of the page. All questions will become property of NACE. Questions and replies may or may not be published under this heading and may be answered either by mail directly to the person asking the information, or published under this heading, or both, at the discretion of the editorial staff. Answers to published questions are solicited. Authors of questions will remain anonymous to readers, while authors of answers may remain anonymous if they request it.

QUESTIONS

No. 64—(Revised. First run in October, 1950, Page 11)
We should like to line a large steel hot water generator which is to operate under constant heat between 160 and 212 degrees F. A permanent lining that can be applied in the field is desired.

No. 70: What surface protection treatment is recommended for magnesium* to afford an optimum paint base, and maximum corrosion resistance for sea water service? Are there any non-destructive methods for inspecting the coatings of surface treated magnesium parts?

* Cerium-Zirconium Alloy Specifically.

No. 71: "Steam Spraying" of paint is a term which has recently come into use. A description of this procedure, and literature regarding it is requested by the originator of this inquiry.

No. 72: Is there available a cement or plastic lining or coating which will withstand constant service in hot softened or distilled water at 180 to 220°F. Applications of interest are new and old boiler feedwater tanks, condensate tanks, and hot water supply tanks. A life expectancy of at least five years is desired.

No. 73: In applying cathodic protection to underwater structures, such as off-shore pipe lines and piling in sea water, using rectifiers, what effect on the protection of the pipe line might be expected from the use of the rectifier only 12 hours a day. Will the pipe line remain polarized for the other 12 hours? Is there any possibility of accelerating local corrosion by this type of operation?

We Want Your Answers To Corrosion Problems

Replies to questions under this heading are solicited by NACE. Tables, graphs and illustrations necessary for a full answer are welcomed. Address your answer to NACE Central Office, giving the question number. Early publication of answers is proposed.

WOW!

The Gal would no doubt be welcome on a desert isle, back row of a movie, Saturday night square dance or any other civil (or un-civil) occasion. All Right, All Right, the Gal's name is Maude and her phone number is Webster 1941. Now, will you read the rest of this?

You'll admit she's pretty, but, have you seen one of our insulating bushings designed especially for gas meter service? How about letting us send you testing samples, the bushings that is, they'll speak for themselves. (Sure wish I had that Monkey's job!)

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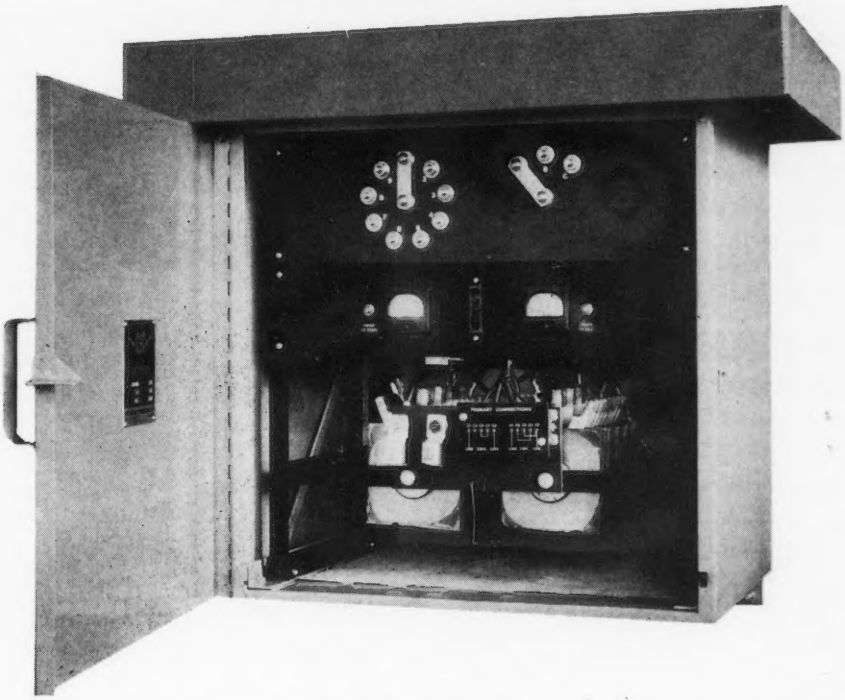

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Persons wishing to submit answers to questions asked under the column heading "Corrosion Problems" are requested to send duplicate copies of their answers to Central Office, NACE, 919 Milam Building, Houston 2, Texas. Names of persons submitting replies will be omitted on request.

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N.A.C.E. Member

Clippings on Corrosion

Extracted from Current Periodicals

UNDERGROUND STEAM SOUGHT FOR NEW ZEALAND POWER

(From Lawton, Okla. Press, Sept. 3, 1950)

New Zealand engineers, drilling to tap underground steam sources at Wairakei in the northern island of New Zealand as a source of heat to produce electrical energy, have reason to believe corrosion may be even more serious than that encountered at Larderello, Italy, where underground steam has been tapped for many years. It may not be possible to use the steam directly in turbines.

•

CORROSION LEAK CAUSES 2000-BARREL OIL LOSS

(From McPherson, Kans., Republican, Sept. 9, 1950.)

Some 2000 barrels of oil which leaked from a Continental Oil Company pipe line on the B. W. Esau farm northwest of Inman was burned off from nearby fields and a creek on which it has collected. The leak, attributed to corrosion, was on a line from Inman to the NCRA Refinery at McPherson.

•

NON-CORROSIVE METALS ARE FEATURES OF HOUSE

(From Santanta, Kans. Chief, Sept. 7, 1950)

Base protection to steel by zinc in a steel home designed and built by Australia's Beaufort Division of the Department of Aircraft Production is reported from Melbourne. The 23-ton structure can be erected on a concrete foundation in two days and moved as a unit if necessary.

CORROSION CAUSED ARMS DUMPING, ARMY ASSERTS

(From Fargo, N. D., Morning Forum, Sept. 10, 1950)

Portage, Wis.—Senator McCarthy (Republican, Wis.) charged Saturday that 120,000 tons of U. S. arms and ammunition destined for China was taken from Indian ports after V-J day and dumped in the Pacific Ocean on state department orders. McCarthy said he had a copy of a letter from the army claiming the ammunition was corroded—that it was improperly stored.

•

STRAY CURRENTS BLAMED IN WATER PIPE RUSTING

(From Lexington, Ky. Herald-Ledger, October 15, 1950)

Sometimes corrosion of metal water pipes and metal objects in the home is greatly speeded by stray electric currents. The continuous conductance of even a small electric current corrodes some metals in a few months.

•

INHIBITORS URGED IN AUTOMOBILE RADIATORS

(From New York Post, Oct. 15, 1950)

E. L. Harrig, manager of Chevrolet service and mechanical department warned motorists that prevention of rust and corrosion in automobile cooling systems is important for continued good service from their cars.

"Judging from the limited use of corrosion inhibitors with water, it is apparent that many motorists do not realize the seriousness of the problem," he said.

•

CORRODED STOVE PIPES CALLED FIRE HAZARD

(From Indianapolis, Ind. News, Oct. 4, 1950)

"If the smoke pipe (of the stove or furnace) shows even tiny signs of corrosion, replace the pipe immediately," Fire Chief Roscoe McKinney warned householders in a special plea during Fire Prevention Week. "Once corrosion starts, it can eat through a pipe fast," he said.

•

SECONDARY ZINC AIDS IN METAL SHORTAGE

(From New York Times, Oct. 7, 1950)

Zinc platers are using zinc balls fabricated from zinc clippings from fabricating plants as a substitute for plating in an effort to offset metal shortages. This is being done despite small lead impurities in the material. Higher plating currents are employed.

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BOOK REVIEWS

BIBLIOGRAPHY ON CATHODIC PROTECTION. By F. A. Rohrman, Executive Director, University of Colorado, Engineering Experiment Station, Boulder, Col. Reprinted from World Oil, July, 1950. 8 pages, 8¼ x 11¼. Per copy, $1.00.

The bibliography covers titles from 1842 through 1949. The 436 titles are coded to indicate aluminum, magnesium and other anode materials and systems of imposing external currents. The author proposes to issue yearly supplements.

Here's how Threshold Treatment with Calgon* controls corrosion in water systems

*T.M. Reg. U.S. Pat. Off.

Calgon is strongly adsorbed on all metals and metallic oxides, especially iron and iron oxide. It controls corrosion by forming a sub-microscopic protective film over all metal surfaces in the water system, thereby insulating them from the oxygen and other corrosive elements of the water.

This film is effective at all pH values above 5.0. In fact, pH values below 7.0 are usually preferable because better control over tuberculation and pitting is obtained in this range.

The only evidence of the film on a polished metal surface is a multicolored iridescence. The film does not build upon itself and in no way impedes the flow of water.

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MONEL COPPER
BRASS ALUMINUM
STAINLESS—TYPES 304 and 316
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Also Tools for application.

FREE

Handy calculator—one side tells you which strap to use for any given corrosive condition; other side determines length and weight of strap required for any binding operation.

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SM-3

NACE

NEW MEMBERS

AND ADDRESS CHANGES

NEW MEMBERS

(Changes Through October 27, 1950)

CALIFORNIA

PUCKETT, GEORGE J., Great Western Div., The Dow Chemical Co., P. O. Box 351, PPittsburg, Cal.

YELTON, PAUL H., California Electric Power Co., P. O. Box 512, Riverside, Cal.

ILLINOIS

MANNING, PAUL D. V., International Minerals & Chemical Corp., 20 N. Wacker Dr., Chicago 6, Ill.

MOORMAN, EARL F., Eng. Matls. Res. & Test Lab., Farm Trac. Eng. Dept., International Harvester Co., 2626 W. 31st Blvd., Chicago, Ill.

ROSS, STERLING L., 821 S. Chestnut, Arlington Heights, Ill.

MASSACHUSETTS

REINHARD, HERBERT W., Protective Coating Co., 257 Cabot St., Newtonville, Mass.

MICHIGAN

COATES, PROCTOR G., Michigan Bell Telephone Co., 618 Boulevard Bldg., 7310 Woodward St., Detroit 2, Mich.

FINLAY, DANIEL F., A & P Finishing & Mfg. Co., 17760 Clarann, Melvindale, Mich.

MISSOURI

BAUMSTARK, WALTER A., The Carpenter Steel Co., 712 Cass Ave., St. Louis, Mo.

COBERLY, CAMDEN A., Mallinckrodt Chemical Works, 3600 N. Second St., St. Louis, Mo.

SANFORD, ROBERT D., Nooter Corp., 1400 S. Second St., St. Louis 4, Mo.

WERNER, SANFORD F., 332 Marion Ave., Webster Groves 19, Mo.

NEW JERSEY

SERVEN, EDWARD J., JR., Worthington Pump & Mach. Corp., Centrifugal Pump Sales, Harrison, N. J.

NEW YORK

BLACKBURN, DOUGLAS B., The Debevoise Co., 74-84 20th St., Brooklyn 32, N. Y.

HERSAM, G. RUSSELL, Prufcoat Laboratories, Inc., 50 East 42nd St., New York 17, N. Y.

KAHN, WALTER C., JR., New York Testing Laboratories, 80 Washington, New York 6, N. Y.

ROBB, EDWARD H., Bisonite Co., Inc., 128 Lakeview Ave., Buffalo 1, N. Y.

TERRY, LeGRAND E., 35-21 149 St., Flushing, N. Y.

OKLAHOMA

BRANTON, JAMES A., Whitehand Hall, University of Oklahoma, Norman, Okla.

PENNSYLVANIA

BLACK, JOHN S., JR., Metal Weld, Inc., 2617 Hunting Park Ave., Philadelphia, Pa.

EGAN, T. E., The Cooper-Bessemer Corp., Lincoln Ave., Grove City, Pa.

JOHNSON, CARL V., H. C. Price Co., Somastic Div., P. O. Box 6120, Philadelphia 15, Pa.

WEST, JOHN F., JR., Pennsylvania Power & Light Co., 901 Hamilton St., Allentown, Pa.

WASHINGTON

POLLOCK, CARL D., Carl D. Pollock Co., Consulting Engineers, 820 New World Life Bldg., Seattle 4, Wash.

TEXAS

COFIELD, WILLIAM W., Transcontinental Gas Pipe Line Corp., General Delivery, Edinburg, Texas.

COLLINS, J. L., P. O. Box 941, Angleton, Texas.

DAY, CLYDE W., Celanese Corp. of America, Box 148, Bishop, Texas.

EXUM, JAMES P., JR., United Gas Corp., 805 Franklin Ave., Beaumont, Texas.

FRITTS, CHARLES J., Magnolia Petroleum Co., Field Res. Labs., P. O. Box 900, Dallas, Texas.

KIMEN, PETER A., Champion Paper & Fibre Co., Box 872, Pasadena, Texas.

LEWIS, WALTER T., Allegheny Ludlum Steel Corp., 4101 San Jacinto St., Houston 4, Texas.

MAYER, GEORGE H., National Carbon Div., Union Carbide & Carbon Corp., 515 Wilson Bldg., Dallas 1, Texas.

STEVENSON, JOHN M., Youngstown Sheet & Tube Co., 610 Continental Bldg., Dallas 1, Texas.

FOREIGN

GERRARD, JOHN S., c/o Kuwait Oil Co., Ltd., Ahmadi, Kuwait, Persian Gulf.

CHANGES OF ADDRESS

(Old Address Follows New Address in Parenthesis)

ALABAMA

HAGER, KARL F., 707 College Hill, Huntsville Ala. (Ordnance Guided Missile Center, Redstone Arsenal, Huntsville, Ala.)

ARKANSAS

GREEN, W. A., V. P. and Gen. Mgr., Midsouth Gas Co., 215 Commerce St., Little Rock, Ark. (Manager Gas Dept., Midsouth Gas Co., 215 Commerce St., Little Rock, Ark.)

CALIFORNIA

BARNHILL, I. HARRY, Chief Tech. Sec., Public Housing Administration, 760 Market St., San Francisco 2, Cal. (Chief, Term. Sec., Public Housing Administration, 760 Market St., San Francisco 2, Cal.)

DONNELLY, LT. PATRICK R., 902 F. Bougainville, Oceanside, Cal. (Tretolite Co., P. O. Box 1005, Midland, Texas.)

GOLDKAMP, CHRIS A., San Diego Gas & Electric Co., P. O. Box 1831, San Diego, 12, Cal. (P. O. Box 1831, San Diego 12, Cal.)

NELSON, H. LLOYD, United Concrete Pipe Corp., Box 425, Baldwin Park, Cal. (Pontusco Corp., Burlington, N. J.)

PHILLIANS, T. F., Shell Oil Co., 1008 W. Sixth St., Los Angeles 14, Cal. (Shell Oil Co., Inc., 1008 W. Sixth St., Los Angeles 14, Cal.)

RADOVICH, FRANK, Nat'l Pipe Coatings, Inc., 6123 Morella Ave., North Hollywood, Cal. (Nat'l Pipe Coatings, Inc., 3480 E. Randolph St., Huntington Park, Cal.)

SMITH, MARTIN B., 3700 Greenhill Rd., Pasadena 8, Cal. (432 Via Vista, Montebello, Cal.)

SNYDER, LOUIS A., 1128 Bay View Ave., Wilmington, Cal. (Richfield Oil Corp., Watson Station, Wilmington, Cal.)

CONNECTICUT

BARNES, R. Y., Aluminum Company of America, P. O. Box 1221, Bridgeport 4, Conn. (Aluminum Company of America, 2210 Harvard Ave., Cleveland 5, Ohio.)

DELAWARE

PERMAR, PHILIP H., 329 Nichols Ave., McDaniel Crest, Wilmington, Del. (E. I. DuPont de Nemours & Co., Inc., DuPont Experimental Station, Wilmington, Del.)

ILLINOIS

FLOURNOY, R. W., 3216 Prairie Ave., Brookfield, Ill. (Corn Products Ref. Co., 3216 Prarie Ave., Brookfield, Ill.)

(Continued on Page 19)

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New Members—

(Continued from Page 18)

FREDENBURG, CHARLES W., Industrial Materials Co., 5424 W. Chicago Ave., Chicago 51, Ill. (Tank Lining Corp., 3227 S. Shields Ave., Chicago, Ill.)
MAURER, ROBERT F., Shell Oil Co., P. O. Box 262, Wood River, Ill. (Shell Oil Co., Inc., P. O. Box 262, Wood River, Ill.)
MILLER, WILLIAM J., Bauer & Black, Div., Kendall Co., 222 W. Adams, Chicago, Ill. (Bauer & Black, 222 W. Adams, Chicago, Ill.)
ORR, C. M., Chicago Bridge & Iron Co., 1305 W. 105th St., Chicago 43, Ill. (Chicago Bridge & Iron Co., 1412 National Standard Bldg., Houston, Texas.)
PAGE, ANDERSON, JR., Bauer & Black, Div., Kendall Co., 2500 S. Dearborn, Chicago, Ill. (Bauer & Black, 2500 S. Dearborn, Chicago, Ill.)

INDIANA

HARDEN, GAIL D., Shell Oil Co., 200 Carroll St., East Chicago, Ind. (Shell Oil Co., Inc. 200 Carroll St., East Chicago, Ind.)
LADENBURG, KURT, Schenley Laboratories, Inc., Lawrenceburg, Ind. (Schenley Distillers, Inc., Lawrenceburg, Ind.)

KENTUCKY

CREEVY, JOSEPH A., Newport Steel Corp., Newport, Ky. (P. O. Box 44, Shreveport, La.)

LOUISIANA

ALLEN, HENRY W., 149 Metairie Lawn Dr., New Orleans 20, La. (Cathodic Protection Service, 4601 Stanford, Houston 6, Texas.)
BESSE, C. PAUL, The California Co., 800 The California Co. Bldg., 1111 Tulane Ave., New Orleans 12, La. (The California Co., 1818 Canal Bldg., New Orleans 12, La.)
BIRD, FRANK S., The California Co., 800 The California Co. Bldg., 1111 Tulane Ave., New Orleans 12, La. (The California Co., 1818 Canal Bldg., New Orleans 12, La.)
KIPP, E. M., Chf. Engr., The California Co., 800 The California Co. Bldg., 1111 Tulane Ave., New Orleans 12, La. (The California Co., 1818 Canal Bldg., New Orleans 12, La.)
O'BRIEN, PAUL S., Socony Paint Products Co., 726 Westmoreland Dr., Baton Rouge, 6, La. (Socony Paint Products Co., 726 Westmoreland Dr., Baton Rouge 12, La.)

MARYLAND

PRUTTON, C. F., Warrington Apt. 2D, 3908 North Charles St., Baltimore 18, Md. (Englemeade Rd., Stevenson, Md.)

MASSACHUSETTS

KARRAKER, ED. L., Shell Oil Co., P. O. Box 181, Waltham, Mass. (Shell Oil Co., Inc., P. O. Box 181, Waltham, Mass.)

MICHIGAN

KENNEDY, TED, Trenton Corp., 408 Wolverine Bldg., Ann Arbor, Mich. (Dearborn Chemical Co., 3240 Book Tower, Detroit, Mich.)

NEW JERSEY

ALLEN, RUSSELL, J., Worthington Pump & Machinery Corp., Harrison, N. J. (Worthington Pump & Machine Co., Harrison, N. J.)
GLIDDEN, WILLIAM E., 120 Morris Ave., Pitman, N. J. (W. E. Glidden, Berwyn, Pa.)
HERSTEIN, FREDERICK E., 812 Carlton Ave., Plainfield, N. J. (General Ceramics & Steatite Corp., Crows Mill Rd., Keasbey, N. J.)
TALBOTT, DANIEL W., Vice Pres., Cooper Alloy Foundry Co., Ramsay & Bloy St., Hillside, N. J. (Copper Alloy Foundry Co., Ramsay & Bloy St., Hillside, N. J.)
TROUPE, RALPH A., 2826 Stevens St., Camden, N. J. (Dept. of Chem. Eng. Speed Scientific School, University of Louisville, Louisville, Ky.)

NEW YORK

DEUBER, CARL G., 531 Ashford Ave., Ardsley, N. Y. (Centro Research Laboratories, Inc., Sleepy Hollow Rd., Briarcliff Manor, N. Y.)
KELLOGG, ANDREW, Niagara Mohawk Power Corp., 300 Erie Blvd., West, Syracuse, N. Y. (Central New York Power Corp., 300 Erie Blvd., East, Syracuse, N. Y.)
MEIER, ALFRED O., Shell Oil Co., 50 West 50th St., New York, N. Y. (Shell Oil Co., Inc., 50 West 50th St., New York, N. Y.)
SMITH, SYDNEY, S., Shell Oil Co., 50 West 50th St., New York 20, N. Y. (Shell Oil Co., Inc., 50 West 50th St. New York 20, N. Y.)

OHIO

COPLEY, JAMES S., National Carbon Div., P. O. Box 6087, Cleveland, Ohio. (National Carbon Co., Inc., 292 Madison Ave., New York 17, N. Y.)
PALMQUIST, WILLIAM W., National Carbon Div., Union Carbide & Carbon Corp., P. O. Box 6087, Cleveland, Ohio. (National Carbon Co., Inc., P. O. Box 6087, Cleveland, Ohio.)

OKLAHOMA

GROOM, CLAUDE H., Dowell Incorporated, 524 Kennedy Bldg., Tulsa, Okla. (GROOM, C. H., JR., Dowell, Incorporated, 524 Kennedy Bldg., Tulsa, Okla.)
LAWLOR, E. W., Pittsburgh Coke & Chemical Co., 711 Thompson Bldg., Tulsa, Okla. (Pittsburgh Coke & Chemical Co., Grant Bldg., Philadelphia 7, Pa.)
SIDWELL, C. V., Box 4037, Tulsa 9, Okla. (2223 E. 24th St., Tulsa 5, Okla.)

PENNSYLVANIA

CIBULA, HENRY J., 3555 California Ave., Pittsburgh 12, Pa. (Koppers Co., Inc., Tar Products Div., Chamber of Commerce Bldg., Pittsburgh, Pa.)
DIECKS, A. NORMAN, 1200 Commercial Trust Bldg., Philadelphia, Pa. (1311 Widener Bldg., Broad & Chestnut Sts., Philadelphia 7, Pa.)
HAGERMAN, CHARLES W., Pennsylvania Salt Mfg. Co., Res. & Dev., Chestnut Hill, P. O. Box 4388, Philadelphia 18, Pa. (Pennsylvania Salt Mfg. Co., Widener Bldg., Philadelphia 17, Pa.)
HESS, ALBERT W., Reynolds Metals Co., 401 N. Broad St., Philadelphia 8, Pa. (401 N. Broad St., Philadelphia 8, Pa.)
STERICKER, WILLIAM, Parkwood Manor—B, Upper Darby, Pa. (Apt. 29, 4016 Garrett Rd., Drexel Hill, Pa.)

WASHINGTON

DALRYMPLE, ROBERT S., 605 Birch, Richland, Wash. (9714 E. Maxwell, Route 3, Opportunity, Wash.)

WEST VIRGINIA

DUGGAN, JAMES J., Carbide & Carbon Chemicals Div., Union Carbide & Carbon Corp., 437 Maccorkle Ave., South Charleston, W. Va. (Carbide & Carbon Chemicals Corp., 437 Maccorkle Ave., South Charleston, West, Va.)

TEXAS

BOCK, MORRIS, Sun Oil Co., 1405 N. Zangs Blvd., Dallas 8, Texas. (Sun Oil Co., 1369 N. Zangs Blvd., Dallas, Texas.)
BOYCE, TREVOR G., P. O. Box 6632, Houston 5, Texas. (Acme Fisher of Texas, P. O. Box 6632, Houston 5, Texas.)
CROWE, RAYMOND, H., Transcontinental Gas Pipeline Corp., 905 M & M Bldg., Houston 2, Texas. (Stone & Webster Service Corp., 905 M & M Bldg., Houston 2, Texas.)
DILLON, CHARLES P., Carbide & Carbon Chemicals Div., Union Carbide & Carbon Corp., Texas City, Texas. (Carbide & Carbon Chemical Corp., Texas City, Texas.)
ENDICOTT, L. A., Carbide & Carbon Chemical Div., Union Carbide & Carbon Corp., Texas City, Texas. (Carbide & Carbon Chemical Div., Texas City, Texas.)
HOLSTEYN, DERK, Shell Oil Co., P. O. Box 2527, Houston 1, Texas. (Shell Oil Co., Inc., P. O. Box 2527, Houston 1, Texas.)
JORDAN, MELVIN N., Texas Pipe Line Co., Basin System, Box 1082, Kermit, Texas. (Texas Pipe Line Co., Basin System, Box 600, Wichita Falls, Texas.)
KEMPER, E. O., Permain Enterprises Inc., 1010 N. Washington, Odessa, Texas. (Permian Enterprises, Inc., P. O. Box 4132, Odessa, Texas.)
MENEFEE, Wm. F., The Texas Pipe Line Co., Box 600, Wichita Falls, Texas. (1915 Eighth St., Wichita Falls, Texas.)
OLSON, THEODORE W., Texas Illinois Natural Gas Pipe Line Co., General Delivery, Wharton, Texas. (1420 Montgomery, Knoxville, Iowa.)
PETTYJOHN, A. R., Carbide & Carbon Chemicals Div., Union Carbide & Carbon Corp., Box 471, Texas City, Texas. (Carbide & Carbon Chemicals Div., Box 471, Texas City, Texas.)
SHAW, GEORGE E., 2609 Sunset Blvd., Houston 5, Texas. (Petro-Chemical Equipment Co., 407 Scanlon Bldg., Houston 2, Texas.)
SHEPARD, HARRY L., National Carbon Div., Union Carbide & Carbon Corp., 3318 Nottingham St., Houston 5, Texas. (National Carbon Co., Inc., 3318 Nottingham St., Houston 5, Texas.)
TURNER, DELBER W., Petrolite Corp., Petreco Div., P. O. Box 2546, Houston 1, Texas. (Petroleum Rectifying Co., P. O. Box 2546, Houston 1, Texas.)
WELSH, MYRON E., Nat'l Bulk Carriers, Inc., 5520 Truett St., Houston 3, Texas. (5520 Truett St., Houston 3, Texas.)
WIMER, CHARLTON J., Wimer Engineering Co., 7534 Military Parkway, Dallas 17, Texas. (Wimer Engineering Co., 2601 Canton St., Dallas 1, Texas.)
ZAJAC, TED S., Shell Oil Co., P. O. Box 2099, Houston 1, Texas. (Shell Oil Co., Inc., P. O. Box 2099, Houston 1, Texas.)

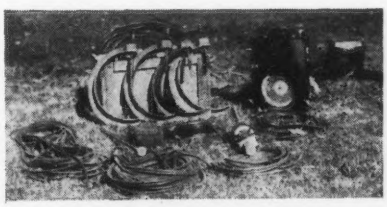
FOREIGN

DOBBS, CECIL I., Creole Petroleum Corp., Corrosion Control Section, La Gunillas, Edo. Zulia, EE.UU. de Venezuela. (Creole Petroleum Corp., Corrosion Control Section, Cabimas, Estado Zulia, EE.UU. de Venezuela.)

NEW NACE CORPORATE MEMBERS

THE EMPIRE DISTRICT ELECTRIC CO.
Joplin, Mo.
Earl Drewelow, Representative
INTERNATIONAL HARVESTER CO.
Chicago, Ill.
Earl F. Moorman, Representative

Advance notices of meetings of organizations other than NACE engaged in corrosion work will be published on request in the "Meetings" column.



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NEW PRODUCTS – Materials – Service – Literature

Fansteel Premium Quality tungsten electrodes, 99.9 Percent Pure is the title of a folder dealing with inert gas and atomic hydrogen arc welding techniques available on request from Fansteel Metallurgical Corp., North Chicago, Ill.

•

Metal Finishing's 19th Annual Edition of its Guidebook and Directory has been issued and is available from the office of Finishing Publications, Inc., 11 West 42nd St., New York 18, N. Y. The 5 by 8-inch book contains 488 pages devoted to a wide variety of information on plating methods and numerous tables of data, formulas, graphs and lists useful in plating operations at all stages.

•

Speedylectric steam-jet cleaners are being made as small as 16 inches wide by 40 inches long for small scale steam cleaning. Using the boiler water itself as resistance, consumption is 15 KW per hour in the JC-20 under normal conditions. Manufacturers are Livingstone Engineering Co., 100 Grove St., Worcester 5, Mass.

•

Econalloy heat exchangers are designed to provide corrosion resistance at a cost lower than for conventional alloy metal units, Martin-Quaid Co., Philadelphia 32, Pa., claims. The units employ corrosion-resistant materials only where required, as flange inserts and for the inner tube which contacts the fluid or vapor being heated. A corrosion-resistant joint is made without welding to the inner tube. The alloy inner tube is expanded into prepared serrations in the ID of the insert flange by special torque limit tools which prevent undesirable stresses. A wide selection of sizes and tube diameters is offered. Bulletin 9-1 can be secured by those interested by writing to 1867 Sedgley Ave., Philadelphia 32, Pa.

•

Pylumin, a dip treatment for aluminum surfaces which results in a surface nonmetallic film of complex basic oxides is described in a pamphlet issued by Pyrene Manufacturing Co., 560 Belmont Ave., Newark 8, N. J. Pylumin powder is mixed in water, forming a solution which acts quickly on aluminum forming a coating which is highly resistant to corrosion and which also serves as a base for paint, lacquer or enamel. The coating is a uniform gray or black depending on the composition of the metal treated. An advantage of the coating, manufacturers state, is its faculty of limiting the spread of corrosion resulting from a break in the painted surface.

•

Unichrome AP-10 Primer showed no signs of failure after 100-hour salt spray tests in which Army-Navy Primer AN-P-656A Zinc Chromate primer failed completely, United Chromium, Inc., 100 East 42nd St., New York 17, N. Y., reports. The AP-10 primer is designed for air and baked drying systems on magnesium, aluminum and other hard-to-coat metals.

•

3M Adhesives, Sealers and Coatings are described in a new catalog issued by Minnesota Mining and Manufacturing Co., 900 Fauquier St., St. Paul, Minn. Coatings to protect metal against corrosives include over 15 "Coro-Guard" systems and five other materials. Over 100 industrial adhesives are detailed in tables. Three tables of properties covering protection of metals against abrasion and corrosion, thermal insulation and sound deadening, adhesives for bonding metal, rubber, glass and other materials, and sealers for various kinds of containers and structures are included.

•

Fiberglas Pipe Line Outer Wrap, a product of Owens-Corning Fiberglas Corp. is designed as an exterior protection for underground pipe lines. It is composed of asphaltic compounds with or without tar components reinforced in all directions by a glass fiber mat and longitudinally by Fiberglas yarns. Manufacturers give characteristics as 1) Protection for enamel coating; 2) prevents damage during lowering-in operation; 3) safeguards against backfill damage; 4) equalizes coating thickness around pipe; 5) lessens soil stresses on coating enamels; 6) keys in with enamel to form a unified protection; 7) has low moisture absorption. A coating system involving bitumen, Coromat pipe wrap and Fiberglas outer wrap applied in that order results in a locking of materials because the bitumen penetrates both wraps readily, manufacturers assert. In tests nearly 12,000 feet of pipe have been wrapped in a day's operations with Fiberglas Outer Wrap without a stop caused by breakage and with a minimum of holidays.

•

Metcoloy No. 2, a high-chrome, high-carbon stainless steel alloy metallizing wire is being used successfully to repair shafts, pump rods or impellers subject to operating conditions involving abrasion and corrosive materials. Metallizing Engineering Co., Inc., 38-12 Thirtieth St., Long Island City 1, New York states many turbine manufacturers are metallizing stainless steel on new turbine spindles because of its excellent wearing qualities. Vol. 5, No. 2 of the Metco News is devoted to Metcoloy No. 2 applications. Copies may be had on request.

•

Fiberglas Bibliography, an 88-page, paper-covered 6 by 9-inch book is the third edition of this comprehensive volume of annotated references to selected articles which have appeared in the nation's press. It is available without cost to engineers, technologists, research investigators and college and university students on request to the Public Relations Director, Owens-Corning Fiberglas Corp., Toledo, Ohio. The 710 references are classified under several aspects of uses, properties, and other data.

•

Bakelite and Vinylite Resins and Plastics used for packaging are described in a folder issued by Bakelite Division, United Carbide and Carbon Corp., 30 East 42nd St., New York 17, N. Y.

•

Metalweld Inc., 26th and Hunting Park Ave., Philadelphia 29, Pa., has issued a 4-page bulletin describing welding repairs and fabrication.

PERSONALS

Robert P. Desch has joined Atlas Mineral Products Co., Mertztown, Pa., as research chemist.

•

Chester R. Austin has been named manager of the development section of the Research Department of Koppers Co., Inc. From 1929 to 1933 he was associated with Ohio State University in ceramic research, and from 1934 to 1948 in ceramic research at Batelle Memorial Institute, Columbus, Ohio.

•

G. Russell Hersam, NACE member, has been named general sales manager of Prufcoat Laboratories, Inc., manufacturer of synthetic resin protective coatings. Mr. Hersam is widely known for his work in the development of cocooning used in laying up the fleet and in storage of army ordnance and military aircraft. **Robert W. Hilton,** formerly New England area manager for the firm has been named assistant general sales manager.

•

R. T. Powers, 53, superintendent of operations of Natural Gas Pipeline Company of America and Texoma Natural Gas Company, died unexpectedly October 7. The company for which he worked is an affiliate of Texas-Illinois Natural Gas Pipeline Company and the People's Gas Light and Coke Company of Chicago.

•

Raymond J. Faust of Lansing, Mich., a member of the American Public Health Association and the Lansing Engineers Club has been named executive assistant secretary of the American Water Works Association.

•

Volney H. Kyle, Jr., has been named vice-president and manager of operations of the Michigan-Wisconsin Pipe Line Company. He was a pioneer in the natural gas transmission business having been with Ford, Bacon and Davis when that firm built the gas line from Monroe, La. to Baton Rouge and New Orleans in 1927.

•

Dr. W. F. Fair, Jr., was the 1950 recipient of the Bingham Medal presented at the November 3 meeting of the Society of Rheology at Hotel New Yorker.

•

Nathan Schofer, formerly South Central Regional Chairman of NACE, will take up residence in Dusseldorf, Germany where he will be project manager on design and construction of an oil refinery in Germany for Hydrocarbon Research, Inc., New York City. A Frankfort firm will handle one phase of the engineering under Mr. Schofer's direction, with the plant scheduled to be built north of Hamburg. Mr. Schofer expects to be in Germany 18 months and may have his family with him later.

Corrosion Abstracts

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GENERAL

• Miscellaneous

1.1

Report on the Conservation of Metals by Corrosion Control. G. Chaudron. Preprint, U. N. Sci. Conf. on Conservation and Utilization of Resources, Lake Success, N. Y. (8/17-9/6/49) 4pp.

A general survey on the protection of metals by corrosion control is presented. Corrosion rates, non-corrosive metals and alloys, the corrosion process, the various corrosive environments and the cost of coatings are considered briefly.

1.1

The Corrosion of Steel and Its Protective Metallic Coatings. A. B. Dove. Paper before Wire Assn., Mordica Memorial Lecture, Chicago, Oct., 1949. *Wire & Wire Prod.*, **25**, No. 1, 29-37+ (1950) Jan.

A very general review includes definition of corrosion, types of corrosion studies, the galvanic series, Inco's factors to minimize galvanic corrosion, protective films, multiple attack, electrochemical attack, protection by low alloy, and protection by metallic coatings such as zinc, nickel, copper, chromium plate, cadmium, tin-zinc, and aluminum. Processes such as hot galvanizing, Sherardizing and metal spraying are reviewed as means of combating corrosion.—INCO.

1.1

Reports of Journees d'Etudes on Corrosion Research. P. Lacombe. **rosion Phenomena — Actual Tendencies** *Revue de Metallurgie* (France), **45**, Nos. 1-2, 2-8 (1948) Jan.-Feb.—ALL

1.1, 6.2

Explanation for the Corrosion of Iron and Steel. R. Mansell. *Western Finishing*, **3**, No. 7, 17-23 (1949). *Electroplating*, **3**, No. 3, 105 (1949) Nov.

The mechanism of rusting, corrosion theories, and methods for the removal of scale from hot rolled steel are discussed.—INCO.

• Reviews

1.3, 6.3, 6.4

FIAT Review of German Science, 1939-1946: Non-Ferrous Metallurgy, Parts I and II. By Max Hansen et al. 22 x 14.5 cm. Part I.—Pp. ix+ 207; Part II.—Pp. ix+ 171. 1948. London: Board of Trade (German Division). Technical Information and Documents Unit, 40 Cadogan Square, S.W.1. (Limited circulation.)

This two-part volume covers almost the whole field of German research work in non-ferrous metallurgy during the war years. The first 57 pages of Part I are devoted to the production, refining, and use of most of the common metals, including potassium, beryllium, magnesium, aluminum, titanium, zirconium, thorium, uranium, manganese, copper, zinc, lead, and antimony; methods for the working and refining of scrap alloys of aluminum, magnesium, copper, zinc, and lead are also dealt with, as is the production of nickel-niobium and iron-vanadium alloys. The remainder of Part I and most of Part II are concerned with the production, processing, properties, and applications of the alloys of beryllium, magnesium, aluminum, nickel, copper, the noble metals, zinc and lead. The last sections of Part II deal with bearing metals, powder metallurgy, and briefly, vacuum melting and casting. Very many references are given, and Part II contains a bibliography, together with author and subject indices. While much of the information has already been published and noted in *Metallurgical Abstracts*, the volume provides an invaluable resume and guide to the results of German investigations during the years 1939-46. It should be noted that the contents of the books are in German.

1.3, 3.5

Researches on Cavitation in the United States and Canada. S. Logan Kerr. *Metaux et Corrosion*, **23**, No. 270, 47-48 (1948).

A review. A bibliography of 12 references is included.—MA.

1.3, 6.2

Rusting and Rust Prevention of Iron and Steel (1946 and 1947) (In German). Heinrich Klas. *Stahl and Eisen*, **69**, 610-612; 636-639, 678-681 (1949) Aug. 18, Sept. 1, Sept. 15.

Reviews literature on the above. Aug. 18 issue deals with soil and water corrosion, hot-water corrosion, steam-boiler corrosion, and individual cases. Sept. 1 issue deals with rust prevention by metallic coatings, and the Sept. 15 issue with use of nonmetallic inorganic and organic coatings for the same purpose. 228 ref.—BLR.

1.3, 8.5

Corrosion. F. L. LaQue, Inco. *Pulp &*

PRIMARY SOURCES OF ABSTRACTS PUBLISHED IN CORROSION

AER—Aeronautical Engineering Review, Institute of Aeronautical Sciences, Inc. 2 East 64th St., New York 21, N. Y.

ALL—The Abstract Bulletin, Aluminum Laboratories, Ltd. P. O. Box 84, Kingston, Onatrio, Canada.

AWWA—Journal, American Water Works Association. Amer. Water Works Assoc., 500 5th Ave., New York 18, N. Y.

BL—Current Technical Literature, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

BLR—Battelle Library Review, Battelle Memorial Institute Library. 505 King Ave., Columbus, Ohio.

BNF—Bulletin; British Non-Ferrous Metals Research Association. 81-91 Euston St., London NW 1, England.

CALCO—Calco Chemical Division, American Cyanamid Corp. Bound Brook, New Jersey.

CE—Chemical Engineering, McGraw Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

CEC—Consolidated Edison Co. of New York, Inc. 4 Irving Place, New York 3, New York.

EW—Electrical World, McGraw-Hill Publishing Co. 330 W. 42nd St., New York 18, N. Y.

GPC—General Petroleum Corp. of California. 2525 East 37th St., Los Angeles 11, Calif.

INCO—The International Nickel Co., Inc. 67 Wall Street, New York 5, New York.

IP—Institute of Petroleum. 26 Portland Place, London W#1, England.

MA—Metallurgical Abstracts, Institute of Metals, London, England. 4 Grosvenor Gardens, London SW 1, England.

ME—Marine Engineering, The Institute of Marine Engineers. 85/88 The Minories, London E. C. 3, England.

MR—Metals Review, American Society of Metals. 7301 Euclid Ave., Cleveland 3, Ohio.

NALCO—National Aluminate Corp. 6216 West 66th Place, Chicago 38, Illinois.

NBS—National Bureau of Standards. Supt. of Documents, U. S. Gov't Printing Office, Washington 25, D. C.

PDA—Prevention Deterioration Abstracts. National Research Council, 2101 Constitution Ave., Washington 25, D. C.

RA—Refrigeration Abstracts, American Society of Refrigeration Engineers. 40 West 40th St., New York 18, N. Y.

RM—Revue de Metallurgie, Paris, France. 5 Cite Pigalle, Paris (9e), France.

RPI—Review of Current Literature Relating to the Paint, Colour, Varnish and Allied Industries, Research Association of British Paint, Colour & Varnish Manufacturers, London. Waldegrave Rd., Teddington, Middlesex.

TDD—Technical Data Digest, Air Material Command—Technical Service Section, Central Air Documents Office, Wright-Patterson Air Force Base, Dayton, Ohio.

TIME—Transactions of Institute of Marine Engineers. 85 The Minories, London EC 3, England.

UOP—Universal Oil Products, 310 South Michigan Ave., Chicago, Illinois.

ZDA—Zinc Development Association. Lincoln House, Turl Street, Oxford, England.

Paper Magazine of Canada, **49,** 81-94 (1948) April.

The seven major factors determining the extent or progress of corrosion are discussed in detail: acidity of the solution, presence of oxidizing agents, temperature, effect of velocity and of films, presence of inhibitors, concentration-cell action (metal ion and oxygen), and incidental factors influencing corrosion-resistance (surface condition stress, heat-treatment, effect of welding). Galvanic corrosion, its definition, the galvanic series, factors affecting galvanic corrosion, and practical aspects of galvanic corrosion are discussed.—INCO.

• Bibliographies

1.4

Corrosion. R. S. Peoples and F. W. Fink. *Metals Rev.,* **22,** No. 10, 4-7 (1949) Oct.

A condensed survey of the literature on corrosion in the last twelve months.

• Directories Including Materials

1.5. 6.5

Chemical Engineering Materials of Construction Review. *Ind. Eng. Chem.,* **41,** No. 10, 2091-2154 (1949) Oct.

This review, based on over 1300 references (mostly 1947-49), deals with properties, fabrication, corrosion resistance, applications, etc. The 16 papers include: "Aluminum Alloys," by E. D. Verink, Jr., and R. H. Brown (pp. 2095-2097); "Wrought Copper and Copper-Base Alloys," by C. L. Bulow (pp. 2108-2114); "Lead and Its Alloys," by G. O. Hiers (pp. 2124-2125); "Nickel and High-Nickel Alloys," by W. Z. Friend (pp. 2126-2132); "Stainless Steels and Other Ferrous Alloys," by M. H. Brown and W. B. DeLong (pp. 2139R-2146); "Tin and Its Alloys," by B. W. Gonser (pp. 2147-2149); and "Less Common Metals," by H. H. Uhlig and D. B. Broughton (pp. 2153-2154), covering titanium, zirconium, tantalum, molybdenum, gold, platinum and silver. The previous review appeared ibid., Oct., 1948. —BNF.

• Books

1.6, 1.5, 5.9

Metal Finishing Guidebook-Directory, 1949. Finishing Publications, Inc., 11 West 42nd Street, New York 18. 468 pp.

This is the 18th edition of what was formerly known as the Guidebook and Directory for the Metal Finishing Industries. As before, there are eight sections giving information on: finishing plant engineering; abrasive methods; cleaning, pickling and electropolishing; plating solutions; surface treatments; and control and testing. New articles on power brushing and bright copper plating have been added, and the older ones brought up to date. A directory and trade name index are also included.—ZDA.

1.6, 5.3, 5.9

Hot-Tinning: Practical Instructions for Hot-Dip Tinning Fabricated Articles and Components. By W. E. Hoare. Med. 8vo. Pp. 112, with 47 illustrations. 1948. Greenford, Middx.: Tin Research Institute, Fraser Rd.; Brussels: Centre de l'Information de l'Etain, 31 Rue du Marais; The Hague: N. V. Billiton Maatschappij (Commerciele Dienst), Louis Couperusplein 19; Columbus 1, Ohio: Tin Research Institute, Inc., 492 West Sixth Ave. (Gratis.)

This booklet deals with the hot-tinning of fabricated articles—not including tinplating. It is issued by the Tin Research Institute as a successor to Dr. C. E. Homer's "Hot-Tinning," published 9 years ago, and includes new methods of tinning cast irons, worked out at the institute since then.

Setting out to be a practical handbook for operators of plants, theoretical discussion and equilibrium diagrams have been kept down to the minimum, while the operations of degreasing, pickling, fluxing, tinning, and finishing are described in detail.

More than one-third of the book is occupied with the tinning of steel; a chapter on the treatment of cast iron includes descriptions of the T.R.I. chloride and nitrate methods, and short chapters follow on tinning copper, other metals, "tinning" with tin-lead alloys, treatment of shop residues, and testing coatings.

The book is well and clearly written. There is a list of references, but an index might have been of value even in so short a volume. The booklet should be useful to those for whom it is designed.—MA.

• Organized Studies of Corrosion

1.7. 6.2

Observations on Corrosion of Ferrous Metals. George D. Lain. American Iron and Steel Institute. "Technical Committee Activities," p. 102-114 (1949).

Briefly discusses atmospheric, bacterial, chemical, high-temperature, soil, and underwater corrosion and stray current electrolysis.—BLR.

1.7

Making the Ocean a Test Tube. F. L. LaQue. Inco. *Scientific Monthly,* **70,** No. 2, 127-132 (1950) Feb.

General review of how the ocean laboratories are put to work at Kure Beach for the general study of corrosion by salt water and salt air and the effects produced by marine organisms on metals, wood, and other materials.—INCO.

1.7, 1.6, 1.1

Chemistry Research, 1948. (Report of the Chemistry Research Board). Chemical Research Laboratory (D.S.I.R.) Brochure, 1949, 82 pp. H. M. Stationery Office, 2s.

There are two sections of metallurgical interest (pp. 11-21, 27-30), these being 1) the work of the corrosion section, including corrosion testing technique (rotor, electrochemical measurements, atmospheric conditions), corrosion behavior of low-alloy steels, organic corrosion inhibitors, influence of surface pre-treatment, study of surface films by stripping and analysis, sulphate-reducing bacteria and other inhibitors; and 2) a certain amount of further work on gallium, germanium and vanadium.—BNF.

1.7, 1.8, 3.5

Oxidation of Iron in the Range 100-400° C. Investigations at Cambridge. U. R. Evans. Investigations at Teddington. W. H. J. Vernon and others. *Nature,* **164,** 909-911 (1949) Nov. 26.

Outlines results obtained independently at above British laboratories. Although the methods employed have been different, the two sets of results are essentially complementary.—BLR.

• Fundamentals

1.8, 6.3

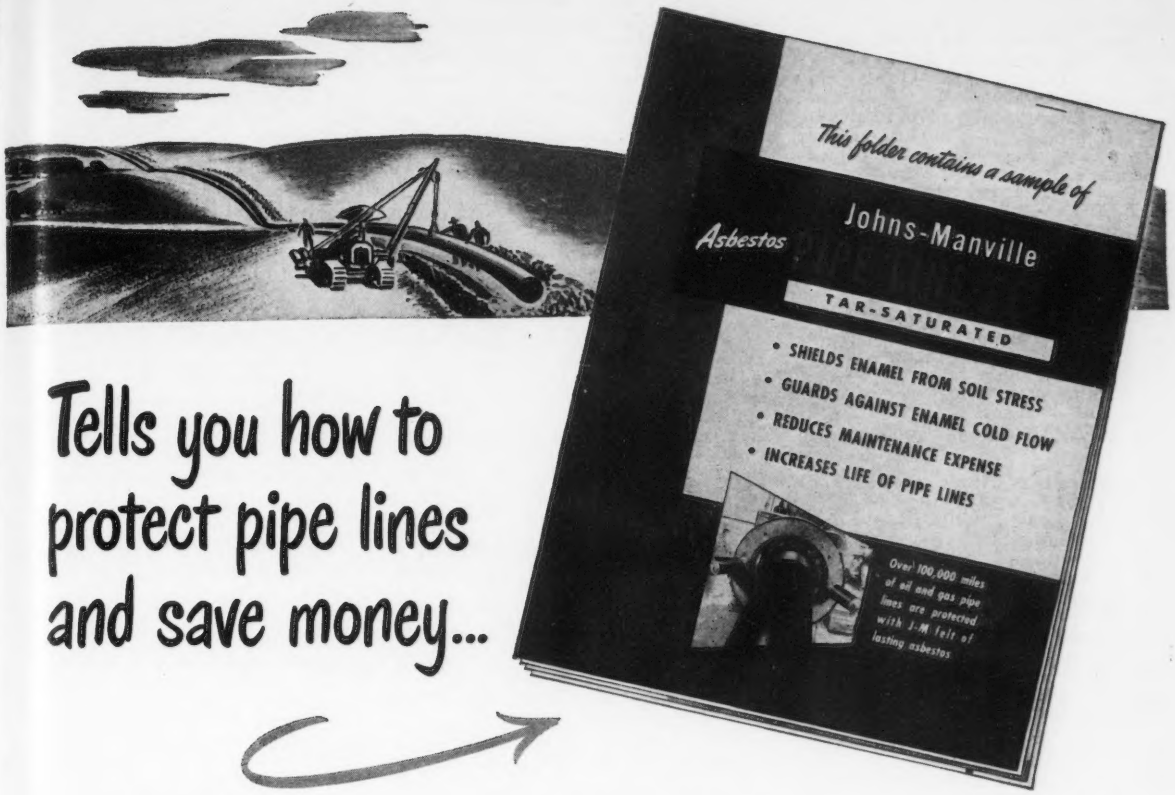
Measurements on the Oxidation-Resistance of High-Melting-Point Alloys—Paper No. 1163. O. Kubaschewski & A. Schneider. *J. Inst. Metals,* **75,** Pt. 6, 403-416, (1949) Feb. *Can. Metals & Met. Inds,* **12,** No. 7, 16-17 (1949) July.

The resistance to oxidation at 1250° C of Cr-W, Cr-Mo, Cr-Ta, Cr-Cb, Cr-Ta-Cb, Cr-Cb-W, Cr-Ta-W, Ni-Cb, and Cr-Ni-Cb alloys, prepared by melting mixed and pressed metal powders, was studied by measuring the decrease in pressure caused by the reaction between the alloy and air in a closed tube, and supplemented by X-ray and microscopic examinations and Brinell hardness measurements at room temperature. In the Ni-Cb system (0-40 Cb) a compound was found of composition Ni_3Cb. The solubility of Cb in Ni is about 15% at 1250° C; the solubility of Ni in Cb is much less. The oxidation-resistance of the alloys is higher than that of pure Cr only in the Cb-rich portion of the α solid solution. The other alloys, especially near the composition Ni_3Cb, are much less resistant to oxidation. Alloys in the Cr_3Cb_2-Ni section showed extreme brittleness with compositions 38 Cb-30 Ni, 44 Cb-20 Ni, and 49 Cb-10 Ni, and high hardness and toughness with 22 Cb-60 Ni and 27 Cb-50 Ni. The oxidation rate of Cr_3Cb_2 was not influenced by additions of Ni, but the oxide was less adherent.—INCO.

1.8, 6.3

On the Mechanism of Oxidation of Nickel-Platinum Alloys Paper No. 1218. O. Kubaschewski & von O. Goldbeck. *J. Inst. Metals,* **76,** 255-267 (1949) Nov.

Oxidation of Ni-Pt alloys containing 0-90 Pt_a at. % Pt was determined by changes in weight after exposure at 600° to 1100° C: oxidation of Ni only occurs. The experimental results are expressed in terms of a corrosion constant, K_o, which is the ratio of the square of the decrease in thickness of the metal layer caused by oxidation to the time; at 850° and 1100° C, K_o is almost constant up to 100 hr. and a simple kinetic process determines rate at these temperatures; at 600° C, neither the parabolic nor the exponential laws apply; and, for a given temperature, K_o is independent of concentration up to 85 at. % Pt and is smaller than the diffusion rate of Ni in Ni-Pt. Rate of oxidation is determined by a diffusion process of Ni^{++} ions (over vacant lattice sites) within the oxide layer. The heat of activation as determined from the log K_o—1/T diagram is a constant (35,500 cal.) up to 85 at. % Pt; the corresponding value for diffusion of Ni in Pt is 43,100 cal. These conclusions are believed to be generally applicable to other similar alloys and may be extended, with certain limitations, to binary systems in which both constituents are oxidizable. 24 references.—INCO.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1.8, 2.3, 3.6

Some Remarks on the Theory of Corrosion Resulting from Local Galvanic Action. (In German.) G. Masing. *Archiv fur Metallkunde*, **3**, 343-346 (1949) Oct.

Presents a critical experimental study of the theories of differential aeration, based on Wicker's and Evans' theories. Diagrams illustrate methods of experimentation. Data are graphed. 16 ref.—BLR.

1.8

Parabolic Oxidation Rates of Metals. Walter J. Moore. *J. of Chem. Physics*, **18**, 231 (1950) Feb.

Rate of growth of thickness of an adherent oxide film on a metal often follows a parabolic law. Discusses mechanism involved on the basis of correlation of literature data on parabolic rate constants for oxidation of Al, Fe, Zr, Ti, Ni, Cu, Co, Zn, and Be.—BLR.

1.8

Oxidation of Metals (In French). N. F. Mott. *Bull. de la Societe Chimique de France*, D84-D88 (1949) Jan.-Feb.

Attempts to establish a new and more satisfactory theory of metal oxidation on the basis of rates of formation of oxide on the metal as a function of time and temperature; mechanism of adherence of oxide to the metal surface; and structure and orientation of the oxide film. 21 ref.—BLR.

1.8, 3.5

Theory of Formation of Oxide Films on Alloys. (In Russian) A. N. Orlov and A. A. Smirnov. *Zhurnal Tekhnicheskoi Fiziki* (Journal of Technical Physics), **19**, 550-559 (1949) May.

Presents further theoretical development of the theory of high-temperature oxidation of binary alloys using a model developed previously by one of the authors. Influence of temperature on rate of oxidation is investigated more thoroughly.—BLR.

1.8

Mechanism of Oxygen Reduction at an Iron Cathode. Walter A. Patrick and Herman B. Wagner. *Corrosion* (Technical Section), **6**, 34-38 (1950) Jan.

Refers to previous articles in which H_2O_2 was assumed to be an intermediate in the corrosion reaction, particularly where ferrous materials are involved. Describes experiments with iron-amalgam cells. Inspection of data show that the greatest yields of peroxide were obtained in alkaline solutions with small current densities. 15 ref.—BLR.

1.8, 3.5

Oxidation of Metals and Reactions in the Solid State. (In French) Jacques Benard. *Bull. de la Societe Chimique de France*, **1949**, D89-D95, Jan.-Feb.

Oxidation at high temperatures was investigated with particular emphasis on kinetics, mechanism of film growth, and influence of crystal orientation on rate of oxidation. Data are charted and illustrated by photo-micrographs. 10 ref.—BLR.

1.8, 3.6

Investigations on the Mechanism of Hydrogen Overvoltage: The Salt Effect. Andre J. de Bethune, *J. Amer. Chem. Soc.*, **71**, No. 5, 1556-1565 (1949).

The hypothesis of Kimball, Glasstone, and Glassner (*J. Chem. Physics*, **9**, 91) (1941) is extended to the case where the solution contains salt as well as acid. If the metallic ions can penetrate into the "saturated" layer and contribute to its electrical charge, they displace hydronium ions from it and cause a rise or drop in the overvoltage, depending on whether the protons discharged are postulated to come from hydronium ions or from water molecules. The magnitude of the rise or drop can be calculated on the simple assumption that the two species of ion penetrate into the saturated layer with equal freedom (apart from any differences in charge). If there is a restriction to the penetration of metallic ions (e.g., because of their hydration shell), the salt effect may be smaller than predicted. The hydrogen over-voltage has been measured as a function of c.d. on a mercury cathode at 25° C in solutions of hydrochloric acid, with and without additions of potassium and calcium chlorides, the results being interpreted to mean that the protons discharged at a hydrogen cathode come from hydronium ions, and not from water molecules; the slight variation of overvoltage with pH in pure acids is also consistent with this interpretation.—MA.

1.8, 3.6

Theory of the Oxidation of Metals. N. Cabrera and N. F. Mott. *Rep. Progress Physics*, **12**, 163-184 (1948-49).

Recent experimental work on the subject of oxidation of metals is analyzed and used to provide a unified theory of the phenomena observed. For the formation of stable films at low temp. it is assumed that the movement of metal ions is controlled by the potential difference between metal and adsorbed oxygen. This theory gives a logarithmic growth law of the type $1/X = A - B \ln t$, where X = thickness and t = time. At higher temp. the parabolic law is obeyed ($X^2 = 2At$), which requires either metal or oxygen to be soluble in the oxide, and the existence of thermodynamic equilibrium at either interface. The value of the constant is: $A = 2\Omega D_i n$, where Ω is the volume of oxide for metal ion, D_i the diffusion coeff. for an interstitial ion, and n the concentration of dissolved atoms (ions and electrons) at the interface. 28 references are given.—MA.

1.8, 5.8

Theory of Adsorption of Gases on Solids. Melvin A. Cook. *J. Amer. Chem. Soc.*, **70**, No. 9, 2925-2930 (1948).

By a theory modeled on that of Brunauer, Emmett, and Teller, an attempt is made to describe the adsorption forces more accurately by the introduction of terms expressing 1) the interaction forces of adsorbed molecules with the adsorbent, and, in an empirical approach, 2) the adsorbate interaction forces. The equations thus derived are found to agree with the sigmoid isotherms over the entire range of relative pressure ($\times$) above 0.05, certain obvious modifications being required to provide agreement for $\times < 0.05$. Heats of adsorption derived from the theory appear consistent with isosteric and calorimetric heats of adsorption, and among the uses of the theory is the extrapolation of adsorption isotherms in the high relative pressure range in order to provide information on surface pressures of films on solids.—MA.

1.8, 5.8

Extrapolation of Adsorption Isotherms to High Relative Pressures and the Determination of Adsorbed Films on Solids. Melvin A. Cook and Douglas H. Pack. *J. Amer. Chem. Soc.*, **71**, No. 3, 791-797 (1949).

The theory of adsorption developed in an earlier paper (*ibid.*, **70**, 2925 [1948]); including, however, the repulsive term previously neglected, is shown to agree with several type-II isotherms over the entire relative-pressure range 0.05-1.0. Methods for handling the complex infinite series of the theoretical equation are outlined, and the convergence and divergence properties of the equation are discussed. The Bangham equation derived from the Gibbs adsorption equation for the surface pressure, π, of an adsorbed film is integrated by means of the theoretical adsorption isotherm, and the calculated surface pressures are shown to be in excellent agreement with data determined by Jura and Harkins from graphical integration of the Bangham equation employing the experimental adsorption isotherms. The theory offers a method for the evaluation of surface pressure from all types of physical adsorption isotherms, including those exhibiting capillary condensation. —MA.

1.8, 5.8

Crystal - Chemical Mechanism of an Oxide Film on Iron at Room Temperature. (Original text in Russian). P. D. Dankov and N. A. Shishakov. *J. Phys. Chem.* (USSR), 1031-1035 (1949) Sept.

It can now be explained that the cause for chemical passiveness of iron is due to the fact that its surface is covered with a protective oxide film of crystalline nature. It was shown, that, in the case of very small ferro-crystals (12-15A), oxygen completely transforms these crystals into oxide with crystal dimensions of 18-20A. The next problem was to investigate the separate stages of the formation of oxide. This was expected to throw light on the mechanism of the oxidizing process. The electrographic investigations, as before, were conducted mainly on ferric films, created by the condensation of its vapor in vacuum in the electrograph itself. The innovations in these problems were the determination of the oxygen effects of aqueous vapor and nature of the substratum. It was concluded that condensed iron produces, also at very careful condensations, electrograms with comparatively wide lines. In some cases the electrograms disclose magnetic oxide instead of iron, even when oxygen is inducted into the instrument. Because in most cases the vacuum in the electrograph was completely satisfactory (approx. 2.10^{-4} mm mercury column) and the life of the iron deposit was sometimes measured to within a fraction of a minute, the formation of oxide was found to be caused by the effect of gases adsorbed by the surface of the substratum. The accuracy of this statement was verified by the case in which iron was condensed over a celluloid film preheated up to 60°-80° C. In such cases the graphs are composed of unusually thin lines. Iron condensed over a highly precooled celluloid film produces a graph showing an unknown hydroxide instead of metallic iron.—FDD.

1.8, 6.3, 4.3

Periodic Phenomena in the Corrosion of Metals (Silver) by Vapour. Rene Dubrisay. *Compt. Rend.*, **229**, No. 17, 829-831 (1949).

A fragment of iodine placed on a sheet of silver—or in a hole in the center of the sheet—produces concentric colored rings. D. measured the dia. of these rings in mono-chromatic (sodium) light

after various periods. If λ is the wavelength of the sodium light, p the order of the ring, and k a constant depending solely on the index of refraction of iodine for the radiation used, the thickness of the iodine film in a given time e = kpλ. The mechanism if this phenomenon is complex. The effect of the temp. up to 100° C is that the rate of corrosion increases with the temp. up to a certain time (about 6 hr. in the conditions of the experiment), after which it decreases with increase of temp. Above 100° C some rings at first increase in size without multiplying, and only a more or less large whitish patch without any interference colors can be observed in ordinary light.—MA.

1.8

The Passivity of Metals. Part IX. The Solubility Product of Freshly Precipitated Ferric Hydroxide. U. R. Evans and M. J. Pryor. *J. of the Chem. Soc.*, **1949**, suppl. issue No. 1, S157-160.

Above solubility product was determined by an electrometric method. This quantity is of interest in the study of certain corrosion reactions. Data are tabulated, charted, and discussed.—BLR.

1.8, 3.6, 6.2

The Anodic Behavior of Iron in Sulfuric Acid. (In German.) Ulrich Frohwalt Franck. *Zeits. fur Naturforschung*, **4a**, 378-391 (1949) Aug.

Deals with electrochemical reactions of anodic passivation and activation of iron in H_2SO_4. A proposed explanation of the anodic passivation mechanism is based on passivation time in relation to anodic current density and flow of the electrolyte. Includes diagrams and graphs. 33 ref.

1.8

Kinetics of the Reactions of Titanium with Oxygen, Nitrogen and Hydrogen. E. A. Gulbransen and K. F. Andrew. *J. of Metals*, **1**, No. 10 (Metals Transactions Section), 741-748 (1949) Oct.—BNF.

1.8, 3.5

The High-Temperature Oxidation of Manganese. Raymond S. Gumick and William M. Baldwin, Jr. ASM Preprint No. 9, 1949, 12 pp.).

The rate of oxidation of manganese in air was determined by measuring the change in weight of specimens exposed at temp. in the range 400°-1100° C. To avoid difficulties due to the extreme brittleness of manganese at high temp., specimens consisting of a layer of manganese, 0.030 in. thick, electroplated on to stainless steel were used. At all temp. in the range studied the oxidation of manganese was found to obey the Pilling-Bedworth law $w^2 = Kt$, where w = the increase in weight in mg./cm.^{2}, t = time in hr., and K is a constant. K is about 0.004 mg./cm.^{2}/hr. at 400° C and 100 mg./cm.^{2}/hr. at 1000° C. Over the range investigated, K is proportional to the reciprocal of the absolute temp. X-ray examination showed that up to 900° C the scale is almost entirely Mn_3O_4; above this temp. MnO appears in increasing amounts and at 1100° C is about 20% of the total. The results obtained are discussed in the light of the stabilities of the oxides of manganese. Application of Valensi's theory of multiple-layed scales [Pittsburgh Internat. Conf. on Surface Reactions, 1948, 156; *Met. Abs.*, **16**, 284 (1949)] suggests that at temp. above 1100° C K may be greater than predicted by the linear relationship with the reciprocal of the absolute temp. —MA.

1.8

An Electron-Diffraction Study of Oxide Films Formed on Nickel-Chromium Alloys. (Discussion on Paper by J. W. Hickman and E. A. Gulbransen.) *J. Metals*, **1**, No. 5 (III), 305-307 (1949) Cf. *Met. Abs.* **16**, 142 (1948-49).

1.8, 5.8

Physical Adsorption on Non-Uniform Surfaces. Terrell L. Hill. *J. Chem. Physics*, **17**, No. 1, 106 (1949).

H. points out that the hypotheses of the Brunauer, Emmett, and Teller (B.E.T.) theory lead to multimolecular adsorption for any value of the B.E.T. constant c for p/p_0 sufficiently close to unity, and in no case to step-wise isotherms, as is suggested by Halsey [*ibid.*, **16**, No. 10, 931 (1948); *Met. Abs.*, **16**, 630 (1949)] for certain conditions.—MA.

TESTING

• General

2.1, 5.4

Accelerated Weathering — So-Called. P. J. Gay. *Paint Tech.*, **14**, No. 168, 543-50 (1949) Dec.

A preliminary report on a lecture delivered in November, 1949, to the London and Midlands section of the Oil and Color Chemists Association. The lecture described the new accelerated weathering apparatus recently installed at the Paint Research Station. It was designed

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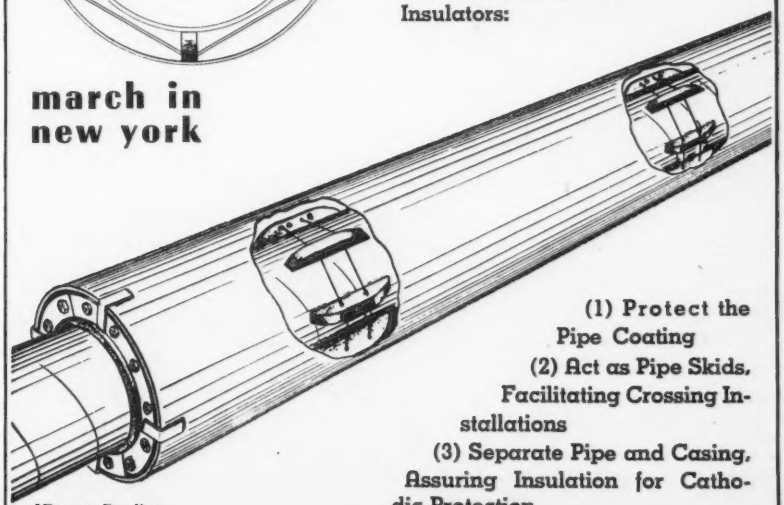

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to balance the following main features of the weather: light and ultra-violet radiation, intensity and duration of water treatment, temperature, and the concentration of oxygen in the atmosphere. The author suggested some ways of improving the poor correlation between accelerated weathering as used at present and natural outdoor weathering. The discussions which followed the paper in London and Birmingham are reported in full (7000 words).

• On Location Tests

2.2, 5.4

Exposure Trials of Weatherwork Paints. Admiralty Chemical Department, Chemical Report No. P/1/49, ACSIL/ADM/49/204. *Journal, The British Shipbuilding Res. Assoc.*, **4**, Abstract No. 3, 110 (1949) Nov.

Details are given of exposure trials of weatherwork paints at three sites, on the roof of a building facing south with the plates exposed at an angle of 45 deg., on ships lying in Portsmouth harbor, and at the extremity of Stokes Bay Pier. The results show that no failures due to corrosion of the metal occurred during the roof-exposure trials. The straight linseed-oil enamels showed serious and extensive cracking, and the behavior of some of the synthetic paints, though greatly superior to that of the linseed-oil enamels, was rather disappointing as regards gloss retention. Some also showed signs of chalking in the nine-month period of the trial. The trials on the ships showed that many alkyd paints will, in fact, chalk in time, and that the mere substitution of alkyd paints for oil types will not eliminate the chalking problem. The failure of some of the systems tested on the Stokes Bay site was very rapid, and was due in most cases to inability to protect the underlying metal. Modifications of the existing DNC/M/73 and DMC/M/75 Specifications and the introduction of an intermediate undercoating between the primer and finishing coat are recommended. —TIME.

2.2, 5.4

The Preliminary Study of the Natural or Induced Aggressiveness of the Soil Before Laying Down Subterranean Conduits—French Applications to Gas Mains and Long-Distance Pipelines. A. J. Maurin. *Metaux et Corrosion*, **23**, Nos. 271/272, 71-78 (1948).—BNF.

2.2, 5.4

Methods of Examining Soil Before Installing Pipes: Application to the Study of the St. Cyr-Bailly (Seine-Et-Oise) Feeder. A. J. Maurin. (In French.) *Metaux et Corrosion*, **24**, No. 292, 280-298 (1949) Dec.

Application of an empirical formula and various charts to study of artificial polarization of experimental tubes plunged vertically into the soil.—BNF.

2.2, 5.4

Tests for Underwater Anti-Corrosive Compositions. Admiralty Corrosion Committee, Hull Corrosion Sub-Committee, ACC/H155/47, ACSIL/ADM/4967. *Journal, The British Shipbuilding Res. Assoc.*, **4**, Abstract No. 3113 (1949) Nov.

Details are given of the preparation and immersion from the Chichester harbor raft of a series of panels coated with formulated anti-corrosive compositions. Two coats of each composition were applied to 100 percent weathered and to 50 percent weathered surfaces to give a standard film thickness, followed by one coat of the same anti-fouling composition of all panels. A similar set of trails is being conducted at Caernarvon. Accelerated rotor tests on all systems are being conducted at the chemical Research Laboratory, Teddington, and at C.L.M.—TIME.

2.2, 6.3, 4.3

Tests of the Resistance of High-Melting-Point (Nickel) Alloys to Corrosion by Combustion Gases. P. Galmiche. *Rev. Met.*, **46**, No. 12, 843-848 (1949).

The resistance of three nickel-base and five nickel-steel alloys to corrosion by combustion gases of arbitrary composition was measured by the loss of weight of electrolytically polished specimens after either continuous or periodically interrupted heating at a given temp. The rates of corrosion were virtually the same for the different alloys in air and in oxidizing combustion gases, with or without the presence of sulfur dioxide. The resistance to dry corrosion was of the same order for all the alloys at the temp. studied. The nickel alloys containing chromium had a slightly higher resistance than the steels. Tests lasting 200 hr. indicated only a small increase in corrosion over 50-hr. tests. The resistance to dry oxidation of the chromium alloys was directly dependent on the film of chromium oxide formed. The tendency to scaling during cooling was more marked with nickel-base alloys, especially at the higher temp. The penetration of oxidation and decarburization along the grain boundaries was approx. the same in "air" and in combustion gases, both with and without sulfur dioxide. On the other hand, the penetration with reducing combustion gases containing sulfur derivatives was greater in the nickel alloys. The presence of chlorine greatly increased the corrosion and appears to act as a catalyst of oxidation.—MA.

• Laboratory Tests

2.3, 3.2, 6.4

Study for Development of New Stabilized High Strength Aluminum Alloys, Report No. KA-496-M-3; U. S. Bureau of Aeronautics, Contract No. NOa(s)—8861. V. J. Pingel and J. J. Dobbins, Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y.

The objective in this study on the intergranular corrosion stabilization of aluminum-copper-magnesium alloys of the 24S type was to prevent by chemical additions the formation of zones of different electro-solution potentials in the grain structure. To this end a micro technique for measuring solution potentials was developed.

Of various aluminum alloys prepared and investigated, none was entirely free from intergranular corrosion. Additions of chromium, titanium, and vanadium in amounts up to 1% appeared to exert beneficial effects.

Alloy compositions containing up to 4.5% copper and up to 1% additions of zinc, tin, antimony, indium, nickel, germanium, cerium, manganese, silver, cadmium, lead, bismuth, ison, silicon, magnesium, tellurium, thallium, tungsten, chromium, titanium, and vanadium were prepared in cast and wrought form and then investigated for susceptibility to intergranular corrosion as related to grain boundary precipitation, depleted grain boundary areas, and micro solution potentials. Cast specimens homogenized at solution temperature for at least 24 hr. gave solution potential values similar to those obtained on wrought specimens treated at the same temperature for at least 1 hr.

The micro solution-potential technique consists of electrically insulating with a transparent plastic film the polished and etched surface of the metal specimen mounted in Lucite or Bakelite, puncturing the film at the desired location with a specially adapted Tukon Hardness Tester, and then determining the solution potential at the point of puncture. By this technique it is possible to examine an alloy of normal grain size with the Tukon microscope (566X) and to measure the solution potential of any part of the microstructure.

A bibliography of 39 references is included.—PDA.

2.3, 5.4

Cell for the Measurement of the Water Permeability of Lacquer Paint Coatings. A. Y. Korolov. *Zavodskaya Lab.*, **15**, 120-22 (1949) Jan.; *J. Iron and Steel Inst.*, 162, Pt. 3, 363 (1949).

The permeability to water of protective coatings is measured by following the loss in wt. of a special cell, the base of which is a 40μ membrane of the coating material; the cell contains water and is placed in a desiccator.—RPI.

2.3, 4.6

A Report on Some Test Methods Designed for Studying the Behavior of (Copper) Alloys in Sea-Water Under Conditions of Rapid Movement. F. L. LaQue and W. C. Stewart. *Metaux et Corrosion*, **23**, No. 274, 147-164 (1948); discussion, 164.

Three test methods are described for studying the behavior of metals and alloys in rapidly moving salt water. Three cupro-nickel alloys (approx. 70% copper, 30% nickel) with both high (0.48-0.49%) and low (0.03-0.04%) iron contents, and two bronzes (G, copper 86.9, tin 9.4, zinc 2.7, nickel 0.9, and lead 0.15%; Marine, copper 86.3, tin 4.7, zinc 4.8, and lead 3.9%) were examined in tube, rod or sheet form. The testing machines were: 1) E.E.S. Machine.—This was specially designed for testing condenser tube material and in essentials consists of a number of discs mounted centrally on a horizontal shaft which is rotated in a tank of salt water. The specimens are attached to, but insulated by Bakelite from, the discs, the standard rotation speed being 380 rpm. This corresponds with linear velocities of 6.5 and 8.5 m/sec. for the tubes and extremities of the rod specimens, respectively. Air is entrained during testing, and in order to maintain a temp. of 30°± 2° C continuous cold-water additions are necessary. 2) Whirligig.—A 61-cm-dia. Monel wheel, to which the specimens are attached, is fixed to the end of an electrically driven vertical shaft and immersed in the sea. The test speeds vary from 1.88 to 5.90 m/sec. for tubular sections and 1.36-6 m/sec. for the rod, and no air bubbles are formed. 3) Jet Impingement Test.—To reproduce the effect of impingement attach on condenser tubes, a jet of salt water with a constant head (10 m) and to which a controlled amount of air can be added, is directed on to the metal surface. The

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effects on the rate of corrosion of speed rotation, solution, temp., air bubbles (comparison of the E.E.S. and Whirligig machines, and the quantity of air in the jet method), and natural sea waters v. synthetic ones are discussed and experimental results summarized in eleven tables. In the E.E.S. machine, the bronzes were most susceptible to the effect of increasing speed which produced greater corrosion, while the high iron content appreciably reduced the corrosion of the cupro-nickel. Using similar speeds, the marine-type bronze and the high-iron cupro-nickels suffered greater corrosion in the Whirligig than in the E.E.S. tests. The reproducibility of the results with the E.E.S. apparatus is good.—MA.

2.3, 6.4

Rapid Determination of Susceptibility of Aluminum Alloys to Intercrystalline Corrosion. Hugh L. Logan. *Metal Prog.*, **57**, 211 (1950) Feb.

Describes technique requiring only 30 min. or less. The specimen is made the anode in a normal NaCl solution. The cathode may be another piece of sheet of suitable size. After 15-30 min. the specimen is mounted for microscopic examination. Results are illustrated.—BLR.

2.3, 3.5

Adsorption Balances for Investigation of Gas Corrosion of Metals and Alloys at High Temperatures. (In Russian). I. A. Makolkin. *Zavodskaya Laboratoriya* (Factory Laboratory), **15**, 1209-1212 (1949) Oct.

Describes and diagrams a newly designed adsorption balance for the above, which is said to be much superior to that of Leontis and Rhines from the points of view of accuracy, sensitivity, and suitability for use at temperatures above 1000° C.—BLR.

2.3, 5.3

The Resistance to Corrosion of Hard Chromium Deposits. P. Morisset. *Metaux et Corrosion*, **24**, No. 291, 247-260 (1949).

M. reviews information on the factors affecting the protection against corrosion afforded by hard chromium deposits. Among these are 1) the structure and porosity of the deposit, 2) the thickness of the deposit, 3) the plating conditions, and 4) the surface finish of the basis metal and of the deposit. The resistance to corrosion by various inorganic and organic media is considered, and a number of experimental observations are described and discussed. M. concludes that the resistance to corrosion of hard chromium deposits cannot be measured accurately and reproducibly. The industrial applications of hard chromium plate are classified according to the corrosive conditions involved, and certain particular applications are considered in some detail. Despite the lack of precision of corrosion tests, from the practical point of view much guidance can be obtained from consideration of all the available data. 18 references are given.—MA.

2.3, 1.8

Mechanism of Overvoltage of Hydrogen on Cobalt in Solutions of Bases and Acids. (In Russian). A. Murtazaev. *Zhurnal Fizicheskoi Khimii* (Journal of Physical Chemistry), **23**, 1247-1256 (1949) Oct.

The above was studied for solutions of KOH from 10 to 0.001 N. and for solutions of 1 N. H_2SO_4, 1 N. HBr, and 0.01-1N. HCl. Experimental method is described. Data are tabulated and charted. 12 ref.—BLR.

2.3, 7.7

Some Observations on the Accelerated ASTM Life Test for Electrical Heating Wires. A. de S. Brasunas and H. H. Uhlig. *ASTM Bull.*, **1949**, No. 161, 31-32, Oct.

The ASTM accelerated life test for electrical heating wires was used with some modifications for evaluating the oxidation resistance of 80Ni-20-Cr and other alloys.

2.3, 4.6

Polarization Method for Accelerated Corrosion Testing of Metals in Sea Water. (In Russian). L. V. Elin and E. Sh. Ryt. *Zavodskaya Laboratoriya* (Factory Laboratory), **15**, 811-813 (1949) July.

Describes modification of method developed originally by G. V. Akim. Modification consists of application of a ballistic galvanometer as the measuring device, thus simplifying the circuit. Corrosion stability is determined from the differential polarization curve, relating the current to the potential difference between two specimens of the metal being tested.

2.3, 5.4

Electrochemical Method for Determining Anti-Corrosive Properties of Lacquer Films. (In Russian.) M. M. Goldberg and N. D. Tomashov. *Zavodskaya Laboratoriya* (Factory Laboratory), **15**, 951-955 (1949) Aug.

Proposes new method for the above, based on use of a lacquered iron cathode and a plain zinc anode in 3% potassium chloride solution. This method makes possible rapid determination of the influence of pigment layer on retardation of the cathodic process, which is directly related to the protective properties of a given coating. A special method for measuring the voltage of several pairs of electrodes without breaking the circuit is described.—BLR.

• Instrumentation

2.4

Ultrasonic Defect Detector for the Non-Destructive Testing of Materials. (In German.) Herbert Krautkramer, Josef Krautkramer and Otto Rudiger. *Archiv fur das Eisenhuttenwesen*, **20**, 355-358 (1949) Nov.-Dec.

Above instrument, described and illustrated, makes it possible to record graphically even small defects in different types of metal. Examples of possible uses are discussed. Includes photographs and diagrams. 10 ref.—BLR.

2.4, 8.4

Inspection Methods of New and Used Oil Country Tubular Goods. M. W. Newman. *Non-Destructive Testing*, **8**, 9-13 (1949) Summer.

Described and illustrated.—BLR.

2.4, 3.6, 3.7, 1.8

Corrosion Patterns in the Iron-Silicon Alloys. (In French.) A. Antonioli and A. Ferri. *Revue de Metallurgie*, **46**, 627-636; discussion (1949) Sept.

Describes a new microscopic method for determination of the orientation of grains in the above and for measurement of the electrolytic solution potential of monocrystals of different orientations. The alloy investigated contained about 4% silicon. The possibility of explaining the corrosion pattern on the basis of the distribution of values of potential in grains of different orientations in polycrystalline materials is suggested. Illustrated. 25 ref.—BLR.

2.4

The Francis Thickness Tester: Application to the Measurement of Electrolytic and Hot-Dipped Tinplate Coatings. K. W. Caufield and W. E. Hoare. *Sheet Metal Ind.*, **26**, No. 264, 753-756+ (1949).

A known small area of the coating is dissolved anodically under controlled conditions and the time of dissolution is used as a measure of the thickness. Modifications of the original instrument are described. The instrument is most suitable for coatings 0.0004 in. thick.—MA.

2.4

Non-Destructive Testing Laboratory. *Electronics*, **22**, No. 5, 154+ (1949)

A brief description of the testing equipment installed at the U. S. Naval Research Laboratory.

Special features are a 10,000,000-V mobile betatron and a 2,000,000-V X-ray machine for inspecting welds, castings, and forgings. Details of the construction of the betatron are given.—MA.

2.4

Ultrasonic Flaw Detector. *Electronics*, **22**, No. 2, 124 (1949).

A brief note describing the ultrasonic flaw detector developed by the Westinghouse Electric Corp. It makes possible the testing of metal objects from 0.25 in. up to 30 ft. thick.—MA.

2.4

White Magnetic Fluid for Crack Detection. *Engineer*, **188**, 533 (1949) Nov. 4.

Describes use of new type of fluid made by ball milling a mixture of approximately equal parts by volume of aluminum and iron oxide prior to dilution with paraffin, or methyl alcohol according to the type of base. Tests with specimens known to contain cracks show that there is no reduction in sensitivity due to the addition of aluminum powder. Surface cracks are shown as white lines. Typical results are illustrated.—BLR.

2.4, 8.9

Use and Abuse of Holiday Detectors. T. H. Gilbert. *Gas*, **82**, 84 (1950) Feb.

High voltage holiday detectors have been in use for some time. They are intended to produce sufficient disturbance by sparking at the holidays to draw the attention of the operator, and they have the greater advantages of greater rapidity of testing and more complete coverage. This article describes their use.—GPC.

• Standardization and Specifications

2.5, 1.7

Tentative (ASTM) Method of Salt-Spray (Fog) Testing (B117-49T). (ASTM Specifications and Tests for Electrodeposited Metallic Coatings, 1949, 31-38.)—MA.

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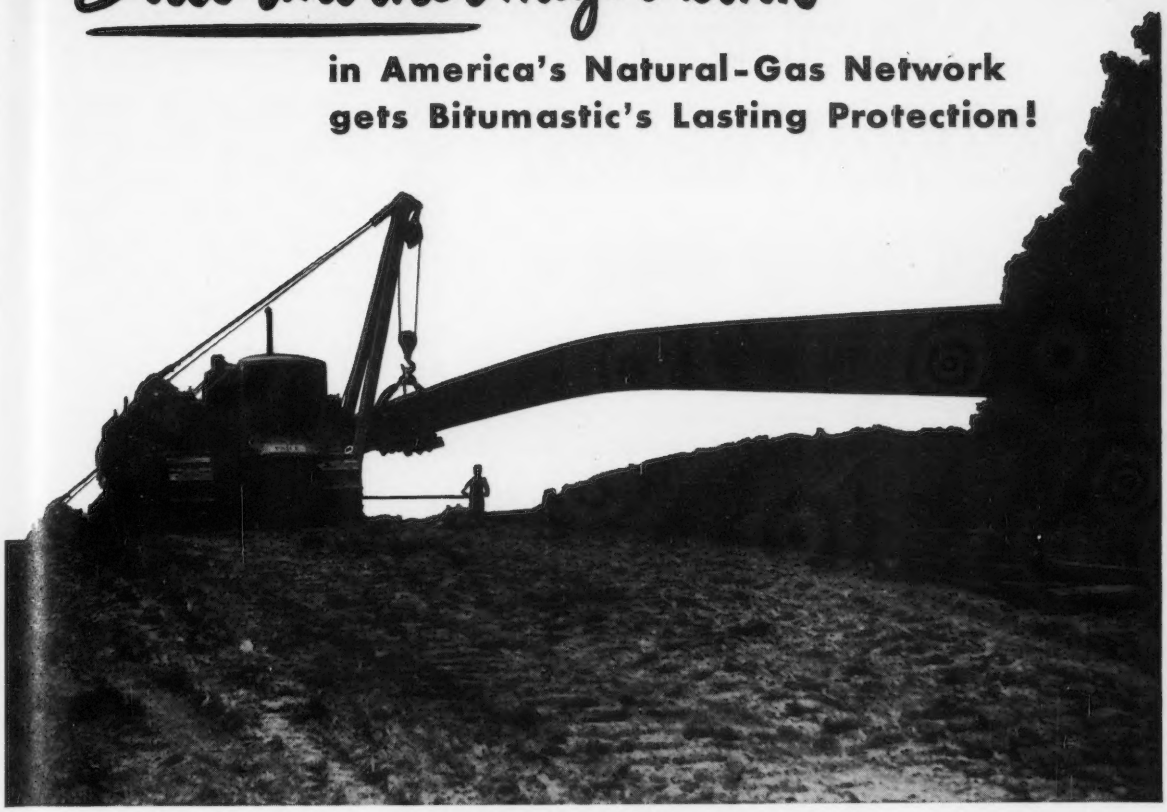

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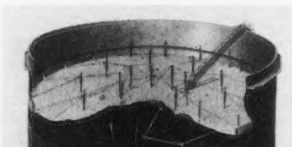

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CORROSION TYPES & INFLUENCING FACTORS

• Types

3.2

The Electrochemical Restoration of Badly Corroded Silver-Copper Alloy Objects. Colin G. Fink. *Science*, **109**, No. 2841, 597 (1949).

A letter. Coins and other metallic objects found in ancient graves and after prolonged soil-burial had the appearance of badly corroded bronze, but in the course of electochemical treatment they were found to be of copper-silver alloys. Evidence gathered during the restoration of a number of such articles indicates that the corrosion was selective in character, the copper going into solution and the silver being protected by cathodic action as long as any metallic copper remained. The silver is thus found embedded in a mass of copper compounds. —MA.

3.2

Corrosion-Damage to Interior of Vessel Walls from Hydrogen Blistering Studied. *Petro. Proc.*, **5**, No. 3, 253-255 (1950) Mar.

Interior damage from H_2 blistering may be considerably more extensive than is indicated by the surface evidence. Information is given on the seriousness of the blistering and embrittlement of walls of vessels and other equipment from H_2 released as the equipment corroded with data from other refineries to give additional light on the subject.—INCO.

3.2

Gases in Steel. E. W. Pierce. *Electric Furnace Steel Proc.*, **6**, 45-46; discussion 65-73 (1948).

Discusses correlation between atmospheric humidity and hydrogen content. —BLR.

3.2, 7.2, 4.6

Corrosion Fatigue Cracking in Steam Piping. Report by British Electricity Authority. *Combustion*, **21**, No. 6, 57-58 (1949) Dec.

Results of an investigation into the causes of corrosion fatigue cracking in a number of British power stations are given. Such cracking occurs in steam receivers and their connections, spray-type desuper-heaters, feed connections to drums and in steam piping. It is recommended that abnormally high stresses due to thermal expansion or structural loads be avoided, layout should avoid formation of condensate during operation or when shut down, and that provision should be made for removal of condensate without contacting massive or vital parts of plant.—INCO.

3.2

Kinetics of Gases in Steel. L. S. Darken. *Electric Furnace Steel Proc.*, **6**, 55-59; discussion, 65-73 (1948).

Presents a model describing the rate of carbon drop in electric and open hearth furnaces based on the interface film. Discusses H_2 and N_2 in the steel bath, hydrogen removal, and the relation between rate of elimination and gas content.—BLR.

• Factors Biological

3.3, 5.4

Present Position of Anti-Fouling Paints. Application to Seaplanes. Karnojitzky. *Tech. et Science Aeronautiques*, No. 4. 197-201 (1948); *J. Iron & Steel*, 163, Pt. 2, 231 (1949).

The problem of marine fouling and the use of anti-fouling paints are discussed with special reference to the protection of seaplane hulls.—RPI.

3.3, 7.2

Control of Marine Fouling by Temperature at Redondo Stream Station of the Southern California Edison Company. W. L. Chadwick, F. S. Clark and D. L. Fox. ASME Paper 49-S-13 (Preprint), 1949, 9 pp.

It was found possible to prevent fouling by marine organisms in two 10 ft. diameter concrete pipes carrying seawater by periodically raising the temperature to just above 38° C for a few hours.—BNF.

3.3

Dye Control of Sulfate-Reducing Bacteria. *Chem. Age*, 61: 494 (1949) Oct. 8.

A review of corrosion by bacteria-produced hydrogen sulfide (T. H. Rogers: *British Sci. News*, 2, No. 23: 322-6) reports that tests of the resistance of sulfate reducing bacteria to a large variety of dyestuffs indicated the flavine-type dyes to be most effective, particularly derivatives of 3:6-diaminoacridine. Experiments to determine the concentration of dye required to inhibit the growth of sulfate-reducing bacteria in varying degrees of infection showed that 1 lb. of dye/100 tons of water is usually sufficient to control anything but the grossest infections if used on successive occasions, the number of dosages being a function of the degree of infection.

• Factors Physical and Mechanical

3.5

Large-Scale Torsional Fatigue Testing of Marine Shafting. S. F. Dorey. *Inst. Mech. Eng., Proc.*, 159, War Emergency Issue No. 46, 399-406; discussion, 407-415 (1948).

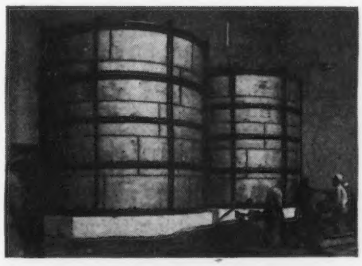
Describes design and construction of a new type of testing machine of the resonance type capable of generating a reversed harmonic torque of up to $\pm 3 \times 10^6$ in.-lb. in a stationary test shaft, at a frequency of approximately 2500 vibrations per min. Reference is made to a specially developed electronic method of speed control capable of regulating the nominal stress in the specimen to within 1%. Includes results of a number of fatigue tests on 9¾-in. diam. mild steel shafts, and also on "Meehanite" cast-iron specimens 6 in. in diam. Concludes with some remarks on scale effect, based on results from ½-in. diam. specimens subjected to reversed torsional-fatigue tests.—BLR.

3.5

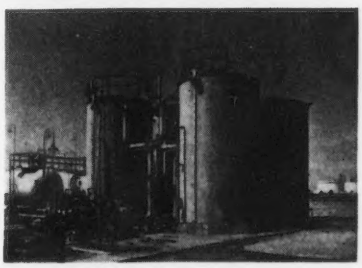
Fretting Corrosion. *Engineer*, 177, 104 (1949) Jan. 28.

Summary of some recent work, based on bibliography of 7 references.—INCO.

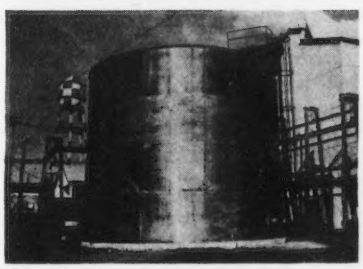
3 Cases where a CORROSION problem was solved by using alloy metals



1. STAINLESS STEEL—The two acid-feed surge tanks shown at the left are located at the Phillips Chemical Company plant at Etter, Texas. They store the nitric acid that is used in the manufacture of ammonium nitrate. The tanks are built of lightweight type 347 solid stainless steel plates with a carbon steel framing.



2. NICKEL—The tanks shown at the left are made of nickel-clad steel plates. They are used for intermediate storage of glycerine by the Shell Chemical Corp., Houston, Texas. Nickel was selected to minimize contamination of the glycerine. The tanks are insulated with magnesia to maintain the temperature of the glycerine during storage.



3. ALUMINUM—This tank is used to store the ammonium nitrate solution being produced at the Spencer Chemical Company's petrochemical plant in Military, Kansas. The shell and bottom are made of aluminum to prevent metallic contamination of the acidic salt solution during storage. The umbrella roof of the tank is made of carbon steel.

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EQUIPMENT

• Engines and Turbines

7.1, 6.2

Modern Bearing Materials Meet Tough Demands of Diesel Service Conditions. E. Crankshaw & G. W. LaPier; B. J. Esarey, W. E. Thill & D. B. Wood. Papers before ASME, 19th Nat. Oil & Gas Power Conf. of the Oil & Gas Power Div. *Power,* **92,** No. 2, 74-77 (1948) Feb.

Selection requires knowledge of bearing requirements and properties of materials. Requirements are adequate fatigue strength, good embedability and conformability, resistance to corrosion, and bondability. Studies show that nearly all bearing materials can be corroded by some set of conditions. Copper-lead alloys are suited for high loading but sacrifice conformability. Cadmium-nickel is good for high loading. Aluminum alloy bearings have high load ability, good embedability and conformability, and high resistance to seizure and corrosion.—INCO.

• Valves and Pipes

7.2, 8.8, 6.4

Aluminum Pipe to Be Used for Transmission of Natural Gas. *Iron Age,* **164,** No. 13, 85 (1949) Sept. 29.

Alabama-Tennessee Natural Gas Company has asked the Federal Power Commission for permission to substitute aluminum alloy pipe for steel for the transmission of natural gas. The 8-inch diameter pipe would be used for a 9500-foot lateral line to serve the Reynolds Alloy Company, Listerhill, Ala. The company expects that the longer wear and reduced maintenance costs for aluminum pipe will defray increased costs of construction.—ALL.

7.2

New Durco Type-B Corrosion-Resisting Plug Valves. *Paper Trade J.,* **129,** No. 12, 105 (1949) Sept. 22.

Two new basic designs, plus a comprehensive range of corrosion resisting alloys, offer a choice for nearly every type of operating and corrosive condition in the process industries. All Durco Type B plug valves have: alloy bodies of Durimet 20, Chlorimet 2 and 3, Durco D-10, pure nickel, Inconel, Monel, and Ni-Resist; hard, hardened or hard-faced plugs with grooves cut after grinding and lapping; Teflon diaphragm to provide a completely corrosion resisting self-lubricating seal; provision for lubrication with bulk or stick lubricant; and proper plug taper, grinding and lapping for continuous seating, long life and positive mechanical operation in corrosive service. Mfd. by Duriron Co., Inc.—INCO.

7.2, 4.5, 2.5, 6.2

Copper Tubes for Underground Service. *Plumbing Trade J.,* **28,** No. 12, 60-62 (1949).

Discusses the service given by copper pipes, and corrosion tests that have been made. Details of properties and specifications of copper pipes are also included.—MA.

7.2, 5.4, 8.5, 8.8

Amercoat Plastic Lined Pipe. *Rayon Textile Monthly,* **29,** No. 4, 109 (1948) Apr.

Plastic lined steel pipe combines structural strength of steel with chemical resistance of vinyl resins. Plastic tube is bonded to steel pipe by special process. It can be used in chemical plants, pulp and paper mills, and other industries where pipe corrosion occurs.

• Pumps and Compressors

7.3, 4.6, 6.2, 8.4

Pumps for Oil Field Brine. *Worthite News,* Jan., 1949; *Oil Gas J.,* **48,** No. 6, 137 (1949) June 16.

Results of a field corrosion test by the International Nickel Co. on Worthite in East Texas oil-field salt water. Installations of Worthite pumps, liners, etc., by Magnolia Petroleum and East Texas Salt Water Disposal Companies are discussed. Worthite has never failed from corrosion in any of the applications mentioned.—INCO.

• Electrical and Telephone

7.7, 5.3, 5.4

Rust-Preventive Coatings for Malleable Iron Insulator Caps. F. Roll. (In German.) *Archiv fur Metallkunde, 2,* No. 8, 254-256 (1948).

Compares results obtained over a period of years with metallic and nonmetallic coatings. Concludes that hot-dip zinc coatings are superior. Results are tabulated, charted, and illustrated.—BLR.

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7.7, 4.5
326 Monel. *Corrosion*, **5**, No. 10, 8 (1949) Oct.
Advantages of 326 Monel sheathing, namely, corrosion and rust resisting, nonmagnetic, easy soldering and its light weight are the reasons for its use to shield power cables for submarine and underground service. Mfd. by Driver-Harris Co.—INCO.

7.7
Stubborn Cable Sheath Corrosion Problem Defeated. L. F. Greve. *Elec. World*, **130**, 102, (1948) Sept. 25.—BL.

INDUSTRIES

• Group II

8.2, 7.1
Corrosion-Resistant and Explosion-Proof A-C Motor. Reliance Electric & Eng. Co. *Elec. Mfg.* **41**, 132, 134 (1948) June.—BL.

8.2
Preventive Maintenance. D. Seitz. *Telephony*, **135**, 49 + (1948) Oct. 23. —BL.

• Group III

8.3
High Efficiency Attained on Multi-Product Line. J. V. Ziemba. *Food Industries*, 21, 69-71 + (1949) Mar.
Description of new plant at Norfolk, Ohio, of Durkees. Vinegar pumped by stainless steel centrifugal pump through stainless steel pipes from wooden tank cars to cypress holding tanks. Starch-slurry mix for preparing salad cream mixed in 200 gal. stainless steel slurry tank and pumped to 300 gal. stainless steel holding tank; processing units jacketed with stainless steel; various other essential units also of unspecified stainless steel.—INCO.

• Group IV

8.4
Rod Pumping. K. T. McCamman, Shell Oil Co. Paper before API, Los Angeles, Spring, 1948. *Oil & Gas J.*, **47**, No. 6, 80, 83-84 (1948) June 10.
Discussion of strengths of sucker rods, tubing, pumping units, and pumps as they affect amount of fluid that can be pumped from any depth. With conventional alloy-steel rods in corrosive wells, or where min. rod stress is fairly low, satisfactory service is limited to less than 26,000 psi. In non-corrosive wells, satisfactory service is obtained at 34,000 psi. New rods of higher strength steel should withstand max. operating stress up to 40,000 psi according to laboratory corrosion fatigue tests. Graphs showing quantitative limitations of sucker rods for pumping systems are given.—INCO.

8.4, 5.8
Corrosion Control. *Oil & Gas J.*, **48**, 107-109 + (1949) Sept. 15.
Reports experience with a variety of inhibitors at West Tuleta gas field, Texas. Describes a semi-polar organic reagent used to coat the pipe and its application by injection. Includes diagrams and charts.—BLR.

8.4, 2.4
Use of Neutralizing Agents for Condensate-Well Corrosion Control. D. A. Shock. *Oil and Gas J.*, **48**, 77-80 (1949) Aug. 11.
Describes apparatus for pH determination in H_2CO_3 solutions. Test result showed that pH could be maintained above 5.5 by addition of neutralizing agents, even in the presence of large CO_2 excesses. Use of magnesium metal was found to reduce attack of CH_3COOH and H_2CO_3 on steel. Injection of Na_2CO_3 into a corrosive well was shown to keep the water above pH 6.0 at well-head conditions. Corrosion of the tubing thus protected was negligible.—BLR.

8.4, 4.3
Corrosion in Petroleum Processes Employing Aluminum Chloride. R. S. Treseder and A. Wachter. *Corrosion*, **5**, No. 11, 383-391 (1949) Nov.
Commercial processes for isomerization of paraffinic hydrocarbons use either of two types of anhydrous liquid catalysts containing aluminum chloride with hydrogen chloride present as a catalyst promoter. The type which consists of an aluminum chloride-hydrocarbon complex has been found to be similar to aqueous hydrochloric acid in its corrosiveness to many alloys. For this catalyst complex, satisfactory inhibition of corrosion in one process has been obtained by addition of about 0.4% antimony trichloride. Factors controlling corrosion by this catalyst complex are discussed, and the mechanism for the corrosive action of this catalyst complex and for its inhibition are presented. The other liquid catalyst commonly used, a liquid melt of aluminum chloride and antimony trichloride, while appreciably less corrosive than the hydrocarbon complex type, is sufficiently corrosive to carbon steel under some plant conditions to require use of resistant alloys such as nickel. Plant corrosion experience with processes employing this catalyst is discussed. Data relating to factors influencing the corrosiveness of this catalyst are presented, and a mechanism for the corrosion reaction is proposed.—TDD.

• Group V

8.5, 7.5, 5.3
Application of Alloy Steel Linings to Tanks Storing Corrosive Pulp Cooking Liquor. H. A. Schmitz and M. A. Scheil. *Corrosion*, **5**, 271 (1949) Aug.
Briefly describes and illustrates test results. Types 347 and 316 low-carbon alloys were found to have considerable advantage over other materials tested.—BLR.

• Group VI

8.6
Solving Corrosion Problems in the Textile Industry. R. B. Seymour and W. L. Worth, Jr., Atlas Mineral Products Co. *Am. Dyestuff Rep.*, **38**, No. 20, 735-737 (1949) Oct. 3.
Methods of combating corrosion problem in textile industry includes applications of modern methods of chemical construction. Application of corrosion resistant materials and other precautionary measures against corrosion are discussed.—INCO.

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• Group VIII

8.8, 4.3, 7.2
How to Move Liquid Chlorine by Pipeline. W. H. Tell, Shell Chemical Corp. *Chem. Ind.*, **65**, No. 1, 52 (1949) July.
A two-mile elevated pipeline for transporting liquid chlorine to Shell Chemical Corp. synthetic glycerine plant at Houston from the near-by Diamond Alkali Co. plant is described. It is made of all-welded 3-in. seamless steel pipe and supported by hangars which, together with expansion loops permit expansion or contraction without stressing. Protection against excess hydrostatic pressure is afforded by a dual rupture disc system connected via a relief manifold to the vapor space of the receiving storage tanks. Internal corrosion of the pipe from dry chlorine is insignificant. Safety relief valves on the storage tanks are protected against corrosion by silver rupture discs. Capacity of the line at a pressure drop of 45 psi. is 6 tons/hr. in summer and 10 tons/hr. in winter.
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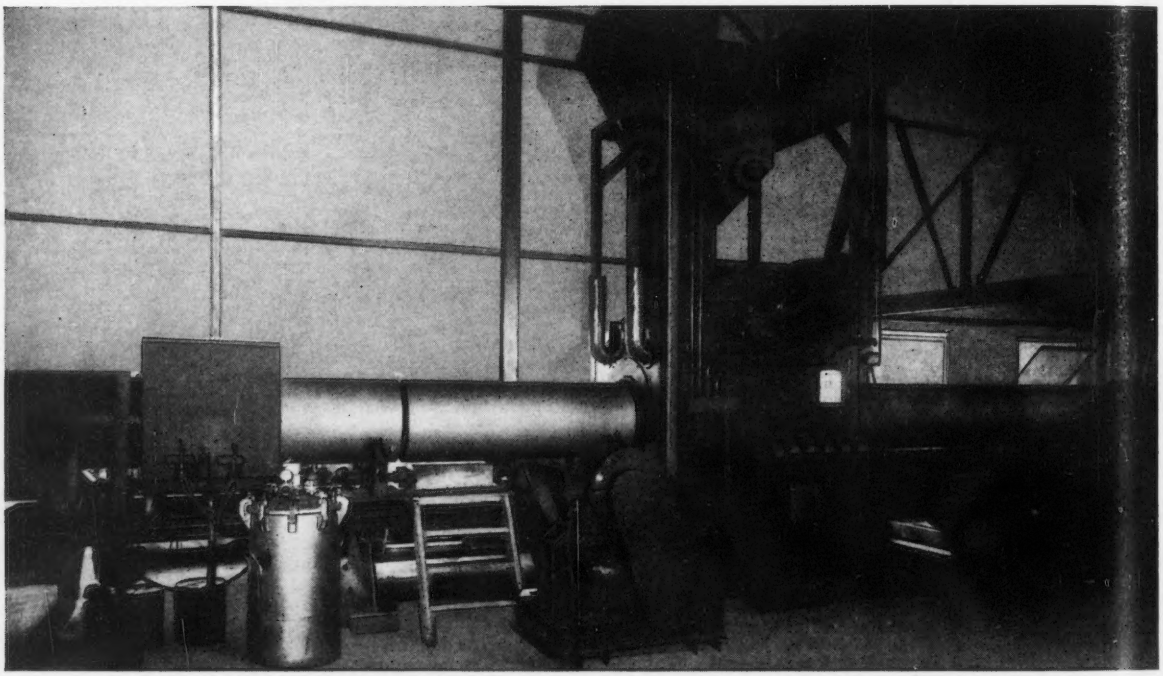

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